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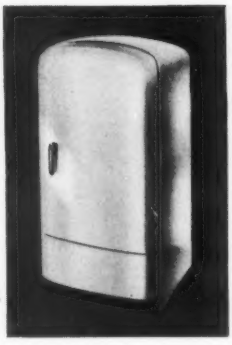

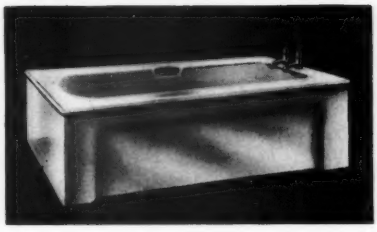

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THIS JOURNAL IS DEVOTED TO THE SCIENCE AND TECHNOLOGY OF PAINT APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING, GALVANIZING, ANODIZING, METAL SPRAYING AND ALL METAL FINISHING PROCESSES.

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THEORY AND PRACTICE

IN any properly organized branch of industry consideration of its technology must range from the highly theoretical and scientific aspects of the subject down to the study of its day-to-day practice and operation. In consequence the technical literature and the activities of the technical bodies associated with it must also attempt to range just as widely, and in the organizing of conferences and in the selection of technical articles for publication there must always be borne in mind the greatly differing needs of the various technical strata which go to make up the industry.

Typical of the nature of the problem has been the recent conference of the Institute of Metal Finishing which was held at Torquay over some three and a half days last month. At this conference fourteen technical papers were presented, a number of which could be classed as being of sufficiently theoretical a nature to interest only scientists and research workers. The remainder however, contained much matter of interest for those responsible for the administration and running of plating shops, and in the main the Conference struck a very effective balance between the conflicting requirements of the membership of the Institute. Those interested solely in the application of organic finishes might justifiably claim to have been somewhat meagrely served, but at the present time, at least, such persons constitute a very small minority of the membership. In any case, finishing departments are very often under common administration, and many of those attending finishing conferences are as much concerned with paint application as with electrodeposition.

As the technical Institute serving an important section of the metal finishing industry it naturally falls to the lot of the I.M.F. to be called upon to enshrine in its proceedings accounts of the latest scientific work relating to its field, and the annual Conference of the Institute is the most effective venue for the discussion of such work. It reflects no little credit on those responsible for the selection of technical papers for presentation at this Conference that such a wide variety of interests were so effectively catered for.

LIGHTER AND BRIGHTER

THIS year the aluminium industry commemorates the hundredth anniversary of the evolution of the metal on a commercial scale, and to mark the centenary there has been staged during the past week a comprehensive exhibition in the Royal Festival Hall and on the South Bank site to demonstrate the progress which has been made in the application of aluminium and its alloys in a wide range of industries.

Not the least noteworthy among the exhibits were some very fine examples of colour anodizing applied to articles made from alloys based on super-purity aluminium. It is perhaps appropriate that in this issue we publish a number of articles relating to the finishing of aluminium and its alloys and to research into the subject. In recent years a number of new processes have been evolved whereby a highly reflective, brilliant finish can be applied to many aluminium alloys of good strength, and considerable interest is being shown in the possibilities of this electro-brightened and chemically brightened aluminium for adoption in a number of applications where the traditional finish has hitherto been nickel-chromium plate. This interest is not unnaturally stimulated by current shortages of nickel, and the consequent failure of plated coatings to withstand weathering when an insufficiently thick nickel deposit has been applied. However, it would be unfair to regard the potentialities of brightened aluminium to exist solely in its application as a substitute material in time of shortage. Developments on the Continent, and many of the exhibits on the South Bank, show only too plainly that lightness, high reflectivity, ease of processing, and good resistance to corrosion can claim serious attention in their own right.

Talking Points by "PLATELAYER"

TOPICAL COMMENT FROM THE MAIN LINES AND SIDE LINES OF METAL FINISHING

IMPOSSIBLE?

THE longer a particular piece of bad practice goes on in industry, the more it becomes acceptable because people have got used to it. For instance, it is standard procedure to mount delicate instruments such as ammeters and voltmeters over plating tanks surrounded by steam and fumes from which they are protected by a sketchily fitting case. Inevitably, the mechanism corrodes and the instrument sticks, or worse still, reads incorrectly; then a new one has to be fitted. There is nothing inherently difficult about making sealed instruments which can be installed without risk of deterioration in corrosive atmospheres. The High Street of most towns can boast a shop showing a watch keeping correct time in a fish tank, while the bottom of the Atlantic Ocean is cluttered up with electrical telegraph repeaters which go on for 20 years or more without being hauled up once.

Yet the concept of specifying hermetically sealed ammeters and voltmeters in a plating shop is about as revolutionary to the average plating engineer as to suggest that he replaces his rectifiers by a small atomic pile. At least one complete range of instruments is available suitable for plating work which will continue to operate in any atmosphere. The cases are airtight and water-tight, terminals and zero adjusters are specially sealed, and the instruments themselves thoroughly oven-dried before installation in their cases; finally they are tested by complete immersion in water for half an hour.

So far as we know, sealed instruments are not yet on the standard selling range of any plating supply house—but they ought to be.

SOME TEST!

TO those who expose samples for atmospheric corrosion testing from time to time, examining and keeping records of a few dozen specimens is quite a chore. How would they like to keep track of 30,000 corrosion test specimens exposed at the Kure Beach Test Station of the International Nickel Company, which has records of some quarter of a million corrosion tests in the files extending over a period of 20 years? The annual report of the Chairman of the company is always worth reading because of the fascinating pieces of information revealed about its operations. Dr. John F. Thompson's latest report is no exception to the rule. The company supplies over four times as much nickel as the rest of the free world put together. Last year's production of nickel was a record and of the 200,000 tons produced, no less than 40 per cent went for defence purposes. Some 16 per cent was used for plating, which, if my calculations are right, would be sufficient to cover almost 100 square miles of surface (which is roughly the size of Birmingham) with a plate of half a thou. thick!

UNCLAD

IT is a strange fact that clad metals have made relatively little headway in this country, yet they have considerable potentialities. In the U.S.A. steel clad with nickel, tin, zinc, copper, stainless steel, and other metals is used much more widely in the fabrication of many articles, especially for the chemical industry. Numerous processes are employed for the production of clad sheet, most of them being mechanical in nature. Electrodeposition methods are used rather less except of course for tin, and to some extent, zinc. One firm has, however, gone into the production of steel sheet clad with very heavy durable deposits of nickel .006-.020 in. thick. At these thicknesses the coatings are substantially non-porous, and being highly adherent can withstand severe forming operations. It is evident that to be competitive with other materials production will have to be mechanized and the plating process itself must be highly efficient. This is achieved by using anodic etching followed by nickel plating from solutions which are basically conventional apart from the fact that they are used at somewhat elevated temperatures (145°-155°F.) and contain a high concentration of nickel.

ROYAL BLUES

THE royal yacht Britannia has just been repainted in blue for the Queen's visit to Norway this month. This is the fifth time the boat has been painted in the last 15 months, and the treatment, it is agreed, was genuinely necessary. Something must be radically wrong with either the selection of the paint or the method of application for the need for such frequent painting to arise even under the most adverse circumstances. What have the suppliers of the paints concerned to say?

• The Rationalization of Industrial Paint-Finishing Systems

by B. van der BRUGGEN

THE ever increasing demands made on the quality of paint, lacquer and varnish coatings or finishes are in no small measure due to the fact that a pleasing outward appearance, if not actually the prime factor in selling the product, at least makes a larger contribution to the result.

An improved quality of external finish, whether for improving appearance or as a protection, is seldom obtainable without the expenditure of more time and more material. In every industrial undertaking concerned with painting and lacquering, therefore, the question arises of choosing the optimum standard of finish, which can be obtained by economically justifiable means. Among the determining factors in the cost of paint and lacquer finishes are: the condition of the surface to be treated, the materials used, the method of application, the drying technique, etc.

In all cases—whether in the planning of new painting shops or in the conduct of those already existing—it is essential to keep informed, in the latter case even at regular intervals, of the prospects offered by new painting and lacquering techniques, materials and equipment. Whether quality can be raised, and cost reduced, whether the existing plant still adequately fulfils its purpose—these are questions which cannot be answered individually, but only in conjunction one with another.

The present article will attempt to clarify some principal aspects of painting and lacquering technique.

The Initial Conditions

Full investigation of the existing, initial conditions is a prerequisite for any attempt at betterment. In an industrial undertaking concerned with painting and lacquering, in which chemical, physical and mechanical considerations equally apply, a survey of existing plant, equipment and methods is of particular importance. Some of the most important questions in the study of the existing state, serving as a basis for improvements, are as follows:

Surface Condition of the work

(*a*) Is the extra cost of improving the present surface condition or finish of the work (before painting) economically justifiable in view of the savings obtainable in the subsequent application of the paint or varnish, having reference to a particular standard of quality?

(*b*) Is it possible to protect the surfaces to be treated from soiling and attack during preceding manufacturing operations and any intermediate stockpiling, by application of paint or varnish?

Paint Coatings, Paint Materials

(*c*) Will the applied paint coating (paint film) be effected or damaged by contamination (dirt, dust) or protuberances (surface roughness)?

(*d*) Is there a superfluity of paint materials (too many kinds or varieties for the same purpose), and does this complicate the working processes?

(*e*) Is documentation available for the working methods and processes used? Are the suitable paint varieties, number of coats, etc. prescribed in writing for particular cases? Are these in structions and date systematically arranged?

(*f*) Are paints diluted or thinned empirically ('by eye'), or on the basis of measurements (*e.g.* viscometer)?

(*g*) What is the position regarding paint storage? Are pipe lines to the painting points (or booths) available?

Paint Application and Equipment

(*h*) Is a cup paint gun still in use where application by piped supply would be possible?

(*i*) Is the compressed-air supply adequate and does it work satisfactorily?

(*j*) Are components still being sprayed or dipped individually, which could by their shape and size profitably be handled in batches?

(*k*) Are components still being sprayed by hand which could more profitably and quickly be dipped or flowed?

(*l*) Are visibility conditions suitable, and the ventilation and air conditioning satisfactory? Are spray booths provided with effective means of removing paint mist?

(*m*) Is painting done after assembly, or could suitable arrangement be made for pre-treatment of the components?

Drying

(*n*) Are air-drying paints with a higher solvent content being used for lack or inadequacy of drying (storing) facilities?

(*o*) Is there a "bottleneck" in the drying section?

(*p*) Are components still being dried in box ovens with corresponding wastage of labour and drying time?

(*q*) Would components be suitable in size and

TABLE I.

SPECIMEN REPORT FORM

No..... Date .....

PRODUCTION

Article.....

Material.....

Finish.....

Dimensions ft..... in..... max..... average..... min.....

Weight lbs..... max..... average..... min.....

Output Pcs/day actual..... programme..... %.....

Operational Stages 1..... 4.....

2..... 5.....

3..... 6.....

WORKING TIME

Time used.....hrs/day

Cleaning .....hrs

Grounding/Rubbing down ..... ,,

Painting ..... ,,

Drying ..... ,,

Handling, stockpiling ..... ,,

Total .....hrs.

No. of Hands.....

Normal Working time:.....hrs/day

Rate/hr.....

Wages, Amount.....

MATERIALS

Paints & lacquers (as used).....

Suppliers (principal).....

Consumption lbs/day.....

Price, lb.....

Cost, per day.....

STORES AND SERVICES

Power, current, KW-hr/day..... cost/day .....

steam, kcal/day..... cost/day .....

Cleaning materials, lbs/day ..... cost/day .....

Maintenance of plant ..... cost/day .....

SUMMARY

Total costs: Time & labour..... (cost)/day

Materials ..... (cost)/day

Services ..... (cost)/day

Total £

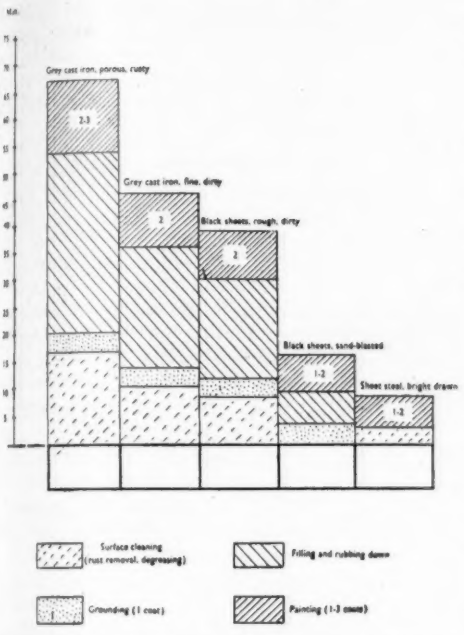


Fig. 1.—Graphical representation of time required for stages in finishing various materials with differing surface conditions.

shape for direct radiation drying in continuous ovens?

Handling

(*r*) Are components still being carried in hand trucks where mechanical conveying means would be advantageous?

(*s*) Are working places and equipment suitably located in regard to conveying paths?

(*t*) Are conveying and equipment matched to each other, or is intermediate handling necessary?

(*u*) Are cleansing and paint-coating effected in batch tanks, or are continuous flow arrangements available?

Filling and Rubbing Down

(*v*) Is work rubbed down by hand, which could be better done wholly or partially by machinery?

(*w*) Is the work wetted by hand during rubbing down, or are automatic sprays available?

Processing Data

In addition to investigating conditions as they exist, as just suggested, the evaluation of production (processing) results is eminently important. Only reliable data on existing paint consumption, time and labour, can furnish a sure foundation for improvement. A progress report or questionnaire of the type illustrated in Table I, individually adapted to the particular conditions obtaining, simplifies the collection of experimental data.

Time and Materials

The costing items of a paint and varnish shop are essentially the following:—

(*a*) *TIME:* Preparatory treatment, applying the paint, drying, waiting periods, and lost time.

(*b*) *MATERIAL EXPENDITURE:* including materials for pretreatment and application.

(*c*) *OVERHEADS:* Power, light, heat, compressed air, etc. Cleaning materials.

Maintenance and depreciation of equipment.

The ratio of time and labour to materials can vary according to actual working conditions. The same applies to overheads.

If it is only desired to practice economy, it should be noted that time saving is not always possible without affecting the expenditure of materials; and, conversely, materials can only be saved with due regard to the time expenditure involved. With reference to overheads, an item which is usually too lightly regarded, it must be carefully considered whether the better utilization of existing equipment will not provide sufficient benefit, and whether any further expenditure on modernization will in fact be justifiable, and pay for itself.

The ratio of time and labour to material expenditure found in practice in a typical modern Swiss painting plant is approximately as follows:

	Swiss Francs
Time and Labour	
Painting and preparing, but excluding cleaning, filling and rubbing down: 4 men, 8 hr. day = 32 manhours at (wage rate + overheads), Frs. 7.00/hour	224.—
Materials	
Paints, ready for spraying or dipping. 30 kg/day at Frs. 5.00/kg. average	150.—
Overheads	
These are included as a surcharge on the labour cost (*e.g.* 100 per cent. surcharge)	
Total Cost	374.—

Condition of Surfaces

The cost of painting or lacquering is considerably enhanced by an unsuitable condition (uneven, rough or porous) of the material to be covered; or when the surface is dirty or corroded.

Dirty surfaces, such as rust, oil, dust, can be prevented by precautionary measures such as protected storage, or a preliminary (temporary) ground coating. To obtain a perfect finish, any surface irregularities must be made good by increasing the thickness of the paint; *i.e.* applying several coats. Coarse abrasives, scratches and

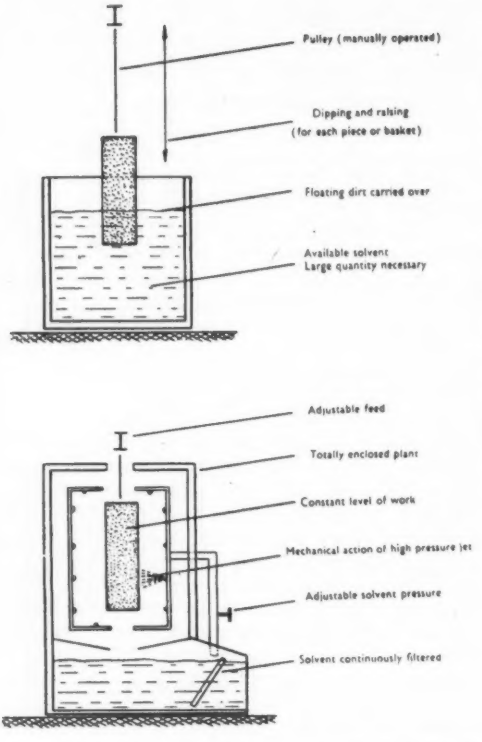


Fig. 2.—Diagrammatic representation of methods of cleaning and pre-treating metal surfaces: above by dipping; below by pressure sprays.

rubbing marks are in this regard less unfavourable than a rough cast or rolled surface. Closer consideration will show that, as a rule, the increased paint expenditure more than balances the extra cost of carefully prepared, fettled castings, or a better sheet metal quality. Fig. 1 shows on the example of a gear casing, the ratio of time and labour expended, to surface finish.

Preparation of Surfaces

The work of preparing surfaces for painting includes scaling, rust removal, degreasing, washing and phosphatizing. In the case of machinery castings, rust and scale can usually be removed by shot-blasting; the exceptions are pieces with already machined surfaces, or of such size or shape as to be incapable of treatment by ordinary shot-blasting equipment. In the case of sheet metal goods, pickling can be used to free the surface from millscale and any rust deposits.

Since the surfaces usually require to be cleaned for machining, the preparation for painting should only require removal of surface rust, degreasing, washing and phosphatizing.

Tedious and expensive cleaning by hand is increasingly being replaced by mechanical cleaning—dipping or spraying. Dipping in baskets on pulleys is being increasingly replaced by continuous flow equipment. A comparison between the methods is shown in Fig. 2.

Types of Paints and Lacquers

The application of paint in a number of different coats enables resistant surfaces of pleasing appearance to be obtained, suitable for any particular purpose. In selecting the appropriate paint materials, attention should be paid, not only to the requirements of the market, or buyer, *i.e.* appearance and quality, but also to processing factors such as technical properties and ease of application. Thus, the "filling power" of the paint depends on the basis used, and is decisive for the number of coats to be applied—thus, also for the time needed. Table II shows three variations of a painting programme; the material assumed is rough sheet steel. The essential characteristics of the two paint materials used in this example are as follows:

Oil Synthetic Resin Basis:
Good covering power = saving time and material.
Longer drying time = increased drying accommodation.
Cellulose Vehicle
Less covering power = increased time and material expenditure.
Quick drying = less drying accommodation needed.)

Consumption of Materials

Quick-drying paints, especially those which dry freely in the air, require a greater number of

Fig. 3.—Diagram illustrating the different material consumption obtained with two types of finish: above, cellulose; below, synthetic resin.

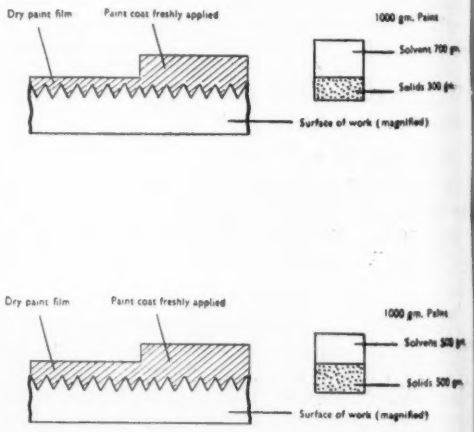


TABLE II.

The influence of the paint material on number of coats, time and labour and drying time.

Material or Surface	Rough Sheet Steel					
Variants	I		II		III	
Painting Sequence						
6. Enamel	Cellulose	2	Cellulose	2	Synth. Resin	1
5. Enamel undercoat	Cellulose	1	Cellulose	1	Synth. Resin	1
4. Surface	Cellulose	1	Cellulose	1	— —	—
3. Filler	Cellulose	3	Oil	1	Oil	1
2. Ground Coat	Cellulose	1	Cellulose	1	Oil-synth. Res.	1
1. Pretreatment	—		—		—	
Total No. of treatments	Cellulose treatment	8	Mixed treatment	6	Oil-synth. resin treatment	4
Total Drying time	12-16 hrs.		17-23 hrs.		24-32 hrs.	

The attainable, short drying time of the treatment (12-16 hrs.) is obtained with eight coats (expenditure of time and material) for a cellulose finish. The times apply for drying at room temperature (19-22° C.)

coats, and thus increase the expenditure of time and materials. This, in turn, increases the expenditure on rubbing down, and, no less, the expense of handling and intermediate stockpiling. The unfavourable ratio between solids content and volatile solvent vehicle, particularly characteristic of the cellulose-based, very quick-drying paints, requires a greater volume of paint to cover a surface with a coat of specified thickness. If special, technical requirements, such as high resistance to oil or alkalis, do not make the use of such paints essential, they merely increase the cost unnecessarily. Too little attention is still being paid to the fact that it is only the solid constituent of the paint, remaining on the surface, which represents the final coating. The process is shown diagrammatically in Fig. 3.

First Paint Application

The adhesion of the first coat of paint governs that of all further applications or coats. Thorough cleaning, the removal of all rust, grease, dust, etc., are the requisites for a successful first coat.

The first coat should be put on as soon as possible, in the case of castings, directly after shot blasting or fettling. This is, however, desirable in all cases, as preventing rust formation and the absorption of oil and grease by surface pores. From the economic aspect, cleaning costs vary in direct ratio to the degree of soiling, and since that usually takes place in the plant itself, during storage and handling, there is every possibility of reducing cleaning cost by such measures as earliest application of the first coat. Table III illustrates conditions in this regard, before and after machining.

Finish Painting

The painting of individual components, before assembly into the finished article, affords a number of advantages. The pieces are smaller and lighter, and thus more suitable for "flow" methods; the necessary equipment is simpler and less expensive.

With the understandable object of making the last coat of paint as good and sound as possible, manufacturers tend to apply this last coat to the finished article. This, however, usually precludes the use of the specially resistant stoving finishes, since the assembled article is frequently either too heavy, too unhandy, or unsuitable for the high temperatures used in stoving. Production econ-

TABLE III.

Process stages in finishing before and after assembly.

1. *Finishing after assembly*

Fabrication of Components

|

Assembly of components

|

Surface cleaning
(Filling, Rubbing Down, Painting)

Larger dimensions and weight impede handling, Time, power cost and space for treatment and drying are increased

|

Despatching or Storing.

2. *Finishing before assembly*

Fabrication of Components

|

Surface cleaning
(Filling, Rubbing Down, Painting)

Single components lighter and handier, hence accelerated handling, painting and drying.

|

Assembly of Components
Careful handling required

|

Despatching or storing.

TABLE IV.

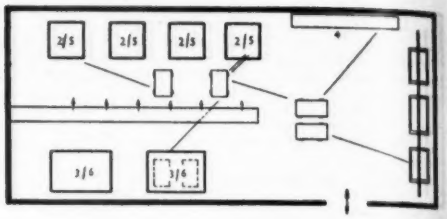
Process stages in ground coating after and before machining

1. *Coating after machining.*

From store or machine shop
Rusty and soiled with grease, cutting oil, etc.
|
Surface Cleaning
Thorough cleaning, usually including rust removal
|
Paint Application
Rarely by dipping; spraying requires shielding of machined areas
|
After-cleaning of machined surfaces.

2. *Coating before machining.*

Surface cleaning
Normally only light soil removal required
|
Paint Application
By dipping or spraying with no surfaces requiring shielding
|
To store or machine shop
Surfaces protected from deterioration



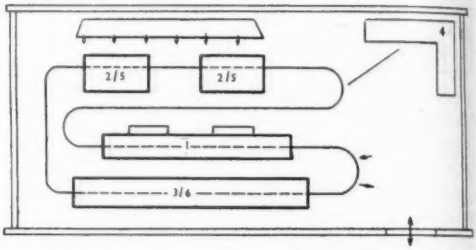


Fig. 4.—Comparative layouts using "static" and "flow" systems: above, installation using dipping baths, drying cabinets and conveyor trucks. Below, arrangement utilizing pressure jet washers, continuous stoving oven and chain conveyor. Key: 1. Surface cleaning. 2. Priming. 3. Drying. 4. Filling and Rubbing down. 5. Finish coating. 6. Drying.

omy requires all round co-operation; thus, the painting and lacquering must be organized as an integral part of the production plan, its requirements and characteristics being given due consideration from the start.

The conditions applying in different cases, are summarized in Table IV.

Work Specifications

Written specifications and processing instructions are particularly valuable in the organization of the painting and lacquering work. As soon as the suitable conditions and requirements for a particular line of work have been established, they should be recorded in writing. In setting up such a " working specification," a definite plan should be followed, the different stages of the work being dealt with in succession. If such data are systematically collected and classified, they will form a

TABLE V.

Typical example of a finishing specification for sheet steel

	Sequence of Operations	Material	Execution
1	Surface cleaning	Phosphoric acid solution	By hand, or dipping, or spraying
2	Ground-coating	Zinc chromate primer	Spraying or dipping, 1 coat.
3	Drying		Stoving, 80-100°C. Drying speed 10-30 min., acc. to temperature
4	Filling, Rubbing Down	Oil-base filler	Patching hollows. Paper No. 320
5	Painting	Synthetic resin stoving enamel	Sprayed once, crosswise
6	Drying		In stove, 120-180°C.; stoving 10-60 min. acc. to temperature and apparatus.
7	Inspection, Cleaning	Solvent naphtha, emery paper 400, polishing pastes	Wipe machined surfaces. Make good paint defects

valuable body of information based on practical experience, for future planning in the paint and lacquer shop. Fig. 7 shows an example of such a working specification, for sheet steel articles.

Processing the Work

The work of painting and lacquering can be organized on two essentially different principles: "static," in which the articles to be treated are stationary; and "flow" in which they are treated while in motion. In the first case, processing and handling are separate; in the second, they are performed simultaneously.

Fig. 4 reproduces the flow sheet of a paint shop on the "static" principle, with dipping tanks, drying cabinets, and truck transport; and of a "flow" layout with pressure spraying for cleansing the pieces, and a continuous tunnel dryer. Communication with the spraying points is by chain conveyor. Obviously, the two layouts are not directly comparable. The undoubted economy of "flow processing" is balanced by the considerably higher capital cost, which also influences the production costs.

Arrangement of Pieces for Processing

Paints and lacquers are usually applied by spraying, dipping or flooding. Spraying is still the most general method; but dipping and flooding are being increasingly used and, correctly applied, can give tangible economic benefits.

Large or heavy articles are almost always sprayed standing upright. The more frequently occurring small parts are treated lying or suspended. The type of suspension is important, particularly for hand spraying, and can have a great influence on productivity.

Upright arrangement is most usual for single pieces. Productivity depends on the skill of the operator.

Lying arrangement is suitable for simple working conditions. It also requires skill and care, and can be recommended in the following cases:

When the shape of the piece allows no other arrangement;
When only one side is to be treated;
When a very thick coat is to be applied;
When the shape is suitable for spraying in batches.

Suspended arrangement has the following advantages:

The operator is saved the labour of turning the work;
The consumption of paint on spraying vertical surfaces is reduced;
and paint coats can be applied free from dust;
Visibility and convenient spraying level can be more easily obtained.

The use of the "continuous flow" system and a chain conveyor enables the operator to be relieved of laborious handling of the work.

Paint Spraying Points

The paint spraying point (booth), is the focus of the painting and lacquering plant. Unfavourable visibility and hygienic conditions should not exist in modern installations; all modern plant, whether tables, stands or booths should have perfect lighting (natural or artificial), and means for complete removal of paint or solvent mist or vapours. In addition, up-to-date spraying points should be arranged for convenient working; details will depend on the nature of the work to be done.

An important step forward in the technique of paint mist and solvent vapour removal is the substitution of the former "dry" methods, using filters, by the "wet" method of water washing the booth walls, which has been considerably developed in detail and improved recently. In most of these arrangements, only the rear wall is so treated.

The solid pigments are precipitated in two stages: such particles as hit the wetted wall are washed down by the water; the principal part is, however, drawn off by a special exhauster fan, through the water curtain, and subsequently washed out. The solids settle in the discharge water tank, and can be recovered. In large plants, the quantities involved are considerable, representing a useful saving, which can be made suitable by reconditioning, for secondary purposes, and thus markedly improve the economy of the plant.

Layout of New Plants

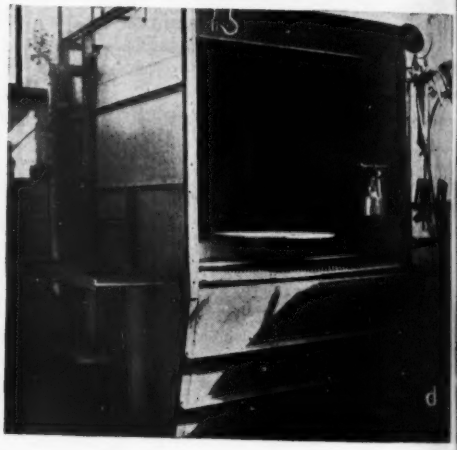
The design and layout of new installations for surface treatment by painting and lacquering, essentially follows the principles of all good, industrial organization. It is necessary to have a clear idea of the aim and purpose of the particular installation: the material to be treated, the quantity to be handled, whether continuous or batch methods are to be used, and what provision is to be made for extensions. The second stage in the development of a project is due consideration of, and selection from, the available possibilities and alternatives. Unwise experimentation may be costly.

The decisive step lies in the choice of abandonment of the old "static" methods, however well tried and tested, which in many cases prove cumbersome and costly, in favour of "flow" production. The remaining considerations concern important details: the manner of application of the paint—by spraying or dipping, in all their many forms; or, should the very latest technical

a

b

c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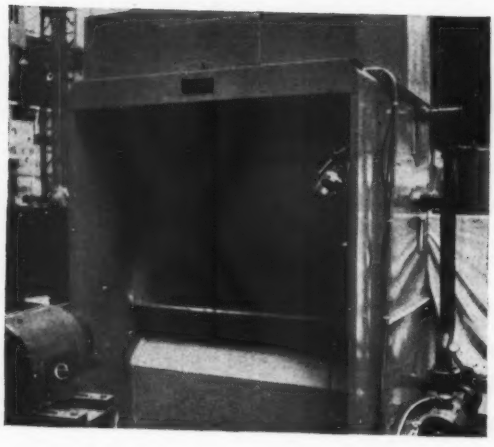
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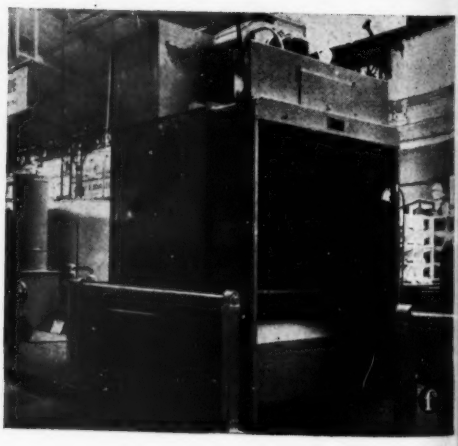
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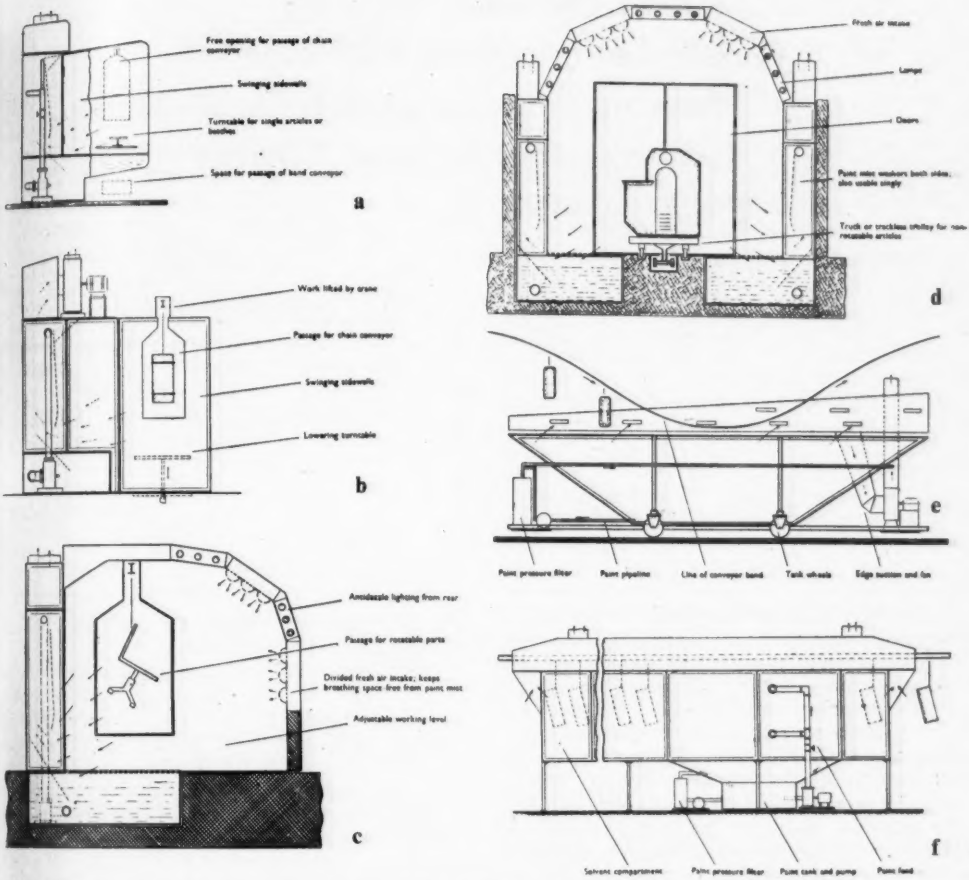


Fig. 6.—Diagrams of modern arrangements for painting and lacquering. a. *Simple spray cabinet with paint mist washer.* b. *Larger cabinet for combined treatment.* c. *Large spray cabinet for working with chain conveyor.* d. *Large cabinet with washer on both sides.* e. *Mobile dipping tank.* f. *Large stationary units for swilling.*

novelty—electrostatic deposition—be used.

Drying, again, can be performed in a number of different ways; by hot air, radiation, infra-red rays, etc. Decisions cannot in this case be taken on general lines, but must be made after mature consideration of the particular circumstances. It remains a fact, however, that modern equipment is suitable for small and medium sized plants, and not the sole prerogative of large installations.

Fig. 5.—A series of typical water-wash spraying booths a—c Cabinets with swinging side walls permitting the handling of unusually long components. The suction fan for the removal of over spray is placed at one side and the illumination is fitted externally. d. *A small spraying cabinet.* e—f. *Two larger pieces of equipment which do not incorporate working areas. Articles to be painted are brought to the spraying point on trucks on which they are painted.*

Fig. 5 a-f (photographs of plants in operation) and 6 a-f (sketches) show some suggestions for modern plants.

Summary

Painting and lacquering is seldom a separate undertaking, but usually a division or department of a larger, manufacturing plant, and the design and operation of such plants follows the general rules of industrial operation and business management. Specialized accounting methods are just as important as a correct adjustment between capital cost and plant utilization. It can be claimed that in a modern painting and lacquering plant, technical, economic and hygienic considerations can not only be compatible with one another, but even be reciprocally complimentary.

CORROSION RESISTANCE of MAGNESIUM ALLOYS

Improved by use of New Low Voltage Electrolytic Chromate Coating

by M. LORANT

A LOW-VOLTAGE alkaline chromate process for depositing protective coatings on magnesium alloys has recently been investigated by H. I. Salmon, M.L. Kronenberg, and F. Ogburn of the U.S. National Bureau of Standards electro-deposition laboratories, under the sponsorship of the U.S. Department of the Army. Coatings produced by this method provide protection against salt-spray corrosion equivalent to that of coatings obtained from other anodizing processes currently used. The new process is potentially more economical than the other methods, however, since it uses a low-voltage power supply and only two chemical constituents other than water.

Light-weight, easily-machined metals are in increasing demand by industry, and magnesium is one of the most important to become available in commercial quantities in recent years. The use of magnesium and its alloys is limited, however, by its low resistance to corrosion—salt-spray corrosion, in particular. Protective coatings obtained from the Bureau's simple alkaline chromate process should lead to wider utilization of magnesium alloys for light-weight equipment and for many aircraft and shipboard components where corrosive atmospheres prevent use of the uncoated metal.

In the Bureau's process alternating current is used instead of the more usual direct current, and the coating is formed on both electrodes. Some material is deposited out of the solution onto the electrodes in the anodizing process, but the coating is mainly material formed by the chemical reaction between the metallic electrode and the components of the electrolyte.

TABLE I

Relation of alkali concentration of bath to salt-spray resistance of coatings deposited from a bath containing 1.0 *M chromate.*

NaOH concentration (Molar)	*Coating thickness* (Mils)	*Corrosion spots* (28 *days' exposure*)
0	Unsatisfactory	—
0.1	1.6	55
0.2	1.7	41
0.3	1.7	36
0.5	1.7	43

TABLE II

Relation of chromate concentration of bath to salt-spray resistance of coatings deposited from a bath containing 0.3 *M alkali.*

K_2CrO_4 concentration (Molar)	*Coating time* (Minutes)	*Corrosion spots* (4 *days of exposure*)
0	20	100
0.1	"	14
0.2	"	13
0.3	"	13
0.4	"	6
0.8	"	6
1.2	"	5
1.6	"	5

The new method for coating magnesium alloys differs from the acid chromate and the HAE anodizing processes in two respects: (1) it operates at a much lower voltage—usually 10 to 12 volts a.c., and (2) the electrolyte contains only two constituents—either sodium or potassium hydroxide and the corresponding chromate. In the Bureau's process, a current of 80 to 140 amp. per sq.ft. is passed through the bath for 20 to 40 minutes, at a temperature of 65 to 75°C. Under these conditions, a coating 1 to 2 mils thick will form on the magnesium alloy electrodes.

The coating is smooth and grey-green in colour, but not as uniform in appearance as either the HAE or the acid chromate coatings. The surface exhibits some sheen if the initial surface is very smooth. Gas absorption measurements (Brunauer-Emmett-Teller method) reveal that the coating has a smaller effective surface area than HAE coatings. If anodized panels are bent or flexed, then the coatings crack on the tension side of the bend and chip or shatter on the compression side.

While the coating distribution is not as uniform as those produced by processes requiring higher voltages, such as the HAE process, it is more even when suitable racking procedures are used. Complete coverage can then be obtained over a limited range of temperature for a given current

(*continued in page* 252)

INTERNATIONAL ENAMELLING CONGRESS

Preliminary Programme of October Meeting

TO mark the 21st anniversary of its foundation the Council of the Institute of Vitreous Enamellers has announced that an International Congress on Vitreous Enamelling will be held in this country commencing on October 9 of this year.

The first British International Congress on enamelling was held under the auspices of the Institute in 1948 when many wartime shortages and restrictions were still operative and the industry had not re-attained its peace time status.

Since that time there has been considerable progress, both in the design of plant and in the operation of the enamelling process, and those participating in the present congress and its attendant works visits will be assured of seeing much of interest.

TECHNICAL PAPERS

A very comprehensive programme of over sixteen technical papers is planned as the technical centre-piece of this Congress. While final titles and authors are in some instances still subject to confirmation, the sessions will include the following contributions emanating from this country and many overseas countries as indicated.

"Sheet Iron Vitreous Enamelling in Australia"
"Problems Associated With Hydrogen Permeability"—Sweden.
"The Enamelling of Holloware"—Germany.
"Quality Standards"—Netherlands.
"The Viscosity of Enamels"—U.K.
"The Thermal Expansion of Enamels"—Netherlands.
"Enamelling in Building Construction"—U.S.A
"The Development of Opacity in White Enamels"—U.S.A.
"Enamelling Practice in Denmark"
"Heat Resisting Enamels"—U.K.
"Practice in Colour Enamelling"—Yugoslavia.
"Developments in De-Enamelling"—France.
"Aspects of Pickling"—U.K.
"Fusion Welding for Subsequent Enamelling"—U.K.
"Development of Screen Printing Processes in the Ceramic Industries"—U.K.
"Fish Scaling Problems"—Germany.

The principal activities of this Congress will be centred on Leamington Spa, where all the technical sessions will be held as well as the main social function. However, in order to provide overseas delegates in particular, with the opportunity to study enamelling works practice in this country, a comprehensive programme of works visits in various parts of the country is being organized to take place before and after the technical meetings.

PROVISIONAL PROGRAMME

Although final details have yet to be completed, the projected programme of this Congress takes the following form.

Sunday—October 9.

Reception and Dinner to overseas delegates by the President and Council on behalf of the Institute and industry at the Park Lane Hotel, London, W.1. The Park Lane Hotel will be the London headquarters of the Congress.

Monday, October 10.

Morning and Afternoon will be taken up with visits to enamelling plants in the London area. In the evening delegates will be received by the Chairman and representatives of the Southern Section of the Institute.

Tuesday, October 11.

Morning—Depart for Leamington Spa visiting works in Oxford en route. Visits for Ladies in the area will also be arranged.

In the evening there will be a reception by the Chairman and representatives of the Midland Section of the Institute.

Wednesday, October 12.

Morning and Afternoon—Technical Sessions at the Town Hall, Leamington Spa.

Evening—Civic Reception by the Mayor and Corporation of the Borough.

Thursday, October 13.

Morning—21st Annual General Meeting of the Institute will be held, followed by technical sessions.

Afternoon Visits to enamelling works in the Midland area.

Evening—A visit to the Shakespeare Memorial Theatre, at Stratford-upon-Avon.

Friday, October 14.

Morning and Afternoon—Technical Sessions at the Town Hall, Leamington Spa.

Evening — Congress Banquet followed by Dancing at Chesford Grange.

Saturday, October 15.

Morning—Technical Sessions at the Town Hall.

Afternoon—A garden party by invitation at the home of the President of the Institute and Lady Briggs.

(*continued in page* 252)

International Enamelling Congress

(*continued from page* 251)

Sunday, October 16.

Travel from Leamington to Manchester by Motor Coach, taking luncheon en route.

Monday, October 17.

Morning and Afternoon—Visits to enamelling plants in the Manchester area.

Evening—Reception by the Chairman and Representatives of the Northern Section of the Institute.

Tuesday, October 18.

Depart from Manchester for a works visit in Bradford and then on to the Lake District where delegates will spend one night.

Wednesday, October 19.

Delegates travel to Edinburgh by motor coach.

Thursday, October 20.

Morning and Afternoon—Visits to enamelling plants in the Clyde-Forth area.

Evening—Reception by the Chairman and Representatives of the Scottish Section of the Institute.

Friday, October 21.

Morning and Afternoon—Further visits to enamelling plants in the area.

Evening—Congress Farewell Dinner.

WORKS VISITS

The list of works to be visited in the various sections during the course of this Congress has yet to be finalized, but already a number of cordial invitations have been extended by companies with enamelling departments, including the following: Belling and Co. Ltd., Benjamin Electric Co. Ltd., Blake Vitreous Enamelling Ltd., R. and A. Main Ltd., Electrolux Ltd., English Electric Co. Ltd., Pressed Steel Co. Ltd., The Parkinson Stove Co. Ltd., Richmonds Gas Stove Co. Ltd., Thomas De La Rue and Co. Ltd., Stoves Ltd., Smith and Wellstood Ltd., Falkirk Iron Co. Ltd.

Preliminary details of the Congress have already been widely circulated by the Institute, both in this country and overseas, and it is expected that a large number of delegates from overseas will participate in all, or most, of the programme. All those who are interested in receiving the final detailed programme, due to be issued later this month, which will provide them with the opportunity of registering for the Congress, should communicate with the Secretary, The Institute of Vitreous Enamellers, Ripley, Nr. Derby, England, to ensure that their name is included in any future mailings relating to the Congress.

Improved Corrosion Resistance of Magnesium Alloys

(*continued from page* 250)

density. For example, if the process is operated at 80 amp. per sq.ft., a temperature of 60°C. is required to obtain complete coverage of specimen panels. At lower temperatures, the panels remain bare near the edges. At higher current densities, the minimum temperature required for complete coverage is higher. However, indications are that temperatures above 75°C. yield coatings having poorer corrosion protection.

The work at the Bureau shows the outstanding characteristic of coatings produced in these alkaline chromate baths to be resistant to salt-spray corrosion. Corrosion resistance of coatings from many baths of various compositions, including the HAE and the acid chromate, were compared with those of coatings produced from this newly developed bath. When the test specimens were exposed to salt-spray in equipment operated according to U.S. Federal Specification QQ-M151 for 12 days, the coatings applied by the alkaline chromate bath appeared to be the most resistant.

The salt-spray protective value of the coating is controlled by the current density and bath temperature. Variations in current between 80 amp. per sq.ft. and 140 amp. per sq.ft. have little effect on the corrosion resistance, but lower current densities yield coatings of inferior protective value. Increasing the temperature above that required for complete coverage also tends to reduce the protection against salt-spray. Direct current has been used in this process to produce uniform coatings on panels in solutions of appropriate composition. The salt-spray tests indicated that these coated panels were somewhat inferior to those coated in the preferred a.c. bath.

As part of the investigation, several organic coatings—such as lacquers or paints—were tested for adhesion to the chromate coating. The adhesion was satisfactory if the specimens were not subjected to bending or flexing. When the panels are bent, loss of adhesion occurs on coatings 0.5 mil or more in thickness because of the failure of the electrodeposited coating. However, the adhesion is satisfactory on thinner coatings.

Reference

Ogburn, F., Salmon, H. I., and Kronenberg, M. L. "Electrolytic Coatings on Magnesium-base Alloys from Alkaline Chromate Solutions." *Plating* 42, 271 (March 1955). This work is a detailed investigation of a process generally described in U.S. Patent 2,314,341, granted to Robert W. Buzzard, March 23, 1943.

The Electrolytic and Chemical Polishing and Brightening of ALUMINIUM and its ALLOYS

A Review by

A. W. BRACE, A.I.M.*

IT is now over 20 years since the Brytal process for electrobrightening of aluminium was announced and since that time a large number of patents have been granted in connexion with improvements to this process and for other types of electrobrightening and polishing baths. More recently there have been announced, and operated commercially, dips which chemically polish and brighten.

This article considers broadly the theory of electrolytic and chemical polishing and brightening, reviews the main types of baths now in use, and discusses their applications. The task of reviewing all the literature on this subject is difficult and largely unrewarding; therefore, detailed attention is confined to the main processes of industrial importance, with mention of other methods which are primarily laboratory methods but which may become of commercial importance.

Electropolishing does not eliminate the need for mechanical preparation, but in some cases it may enable it to be substantially reduced, and a smooth finish to be produced. This polished surface is relatively free from distortion, since the flowed metal layer normally present after mechanical polishing is removed by such treatments.

In the published papers the terms "polishing" and "brightening" are used rather indiscriminately. Broadly the distinction for the purpose of this account is as follows. A polishing bath is taken to be one which can smooth the surface and remove appreciable quantities of metal if required. A brightening bath is regarded as one whose main function is to increase the total reflectivity of the metal surface as compared with its original value. Brightening is normally accompanied by some polishing, but it is possible to polish the surface of a metal and have but small effect on its total reflectivity.

* Metallurgist, The Aluminium Development Association, London, W.1.

Early Work

Early work on these processes was primarily directed towards obtaining the maximum reflectivity, particularly on aluminium of fairly high purity, *i.e.* 99.5 per cent and upwards. The early processes such as Brytal can be described as electrobrightening treatments since the amount of metal removed is relatively small, but improvement in the total reflectivity is quite marked. The theoretical justification for this classification is dealt with later.

Processes subsequently developed have utilized baths based on phosphoric acid: these are capable of removing large quantities of metal and will electropolish certain non-homogeneous aluminium alloys, such as those containing some copper and silicon. These baths can therefore be said primarily to polish, although with aluminium of high purity they will also brighten on account of the removal of surface imperfections present in mechanically polished material.

Theory of Electropolishing

The mechanism of electropolishing is not yet fully understood, although its main principles are now fairly well established. These can be applied to all metals, and in some cases electropolishing solutions can be used successfully on more than one metal with only slight changes in the condition of operation.

The technique of electropolishing is of recent origin and no literature reference can be traced prior to 1925. Subsequently, Burns and Warner[1] took out a patent for an anodic cleaning process using a phosphoric-acid electrolyte, and recorded that under certain conditions bright surfaces were obtained on steel. During subsequent years several workers developed the use of sulphuric acid for the "electrolytic bright dipping" of steel. In 1930, Figour and Jacquet[42] applied for a patent covering a phosphoric acid-ether mixture for electrolytic polishing of aluminium.

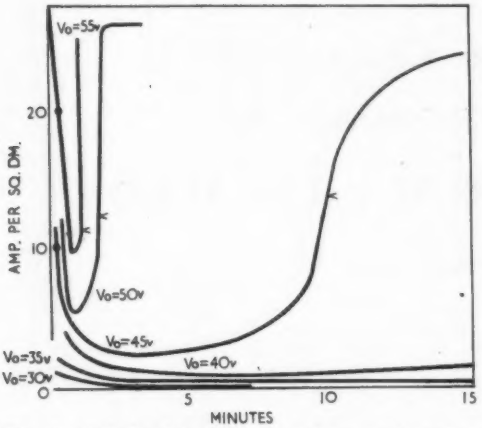
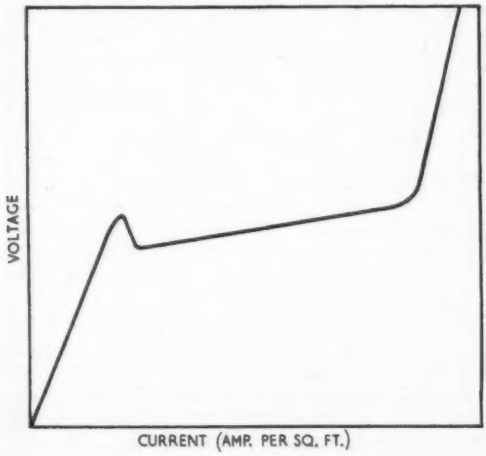


Fig. 1.—Relationship between voltage and current density with time, obtained when electropolishing 99.99 per cent aluminium in a perchloric-acetic anhydride bath (4). (The arrow heads indicate the points at which etching occurred.)

However, it was not until 1935 that the phenomenon was studied carefully and reported in the well-known papers of Jacquet[2,3]. Initially in this work the orthophosphoric-ether electrolyte was studied for the electropolishing of copper, although mixtures of perchloric acid and acetic anhydride were successfully used later for other metals such as brass, lead, tin, steel and aluminium. Jacquet's work was primarily aimed at developing a method for the preparation of metallographic specimens, but his studies provided the basis for the theoretical explanation of the mechanism of electropolishing. Owing to the practical hazards involved in the use of perchloric acid (there is considerable explosion risk) and ether, the commercial application of electropolishing has been based mainly on mixtures containing phosphoric acid as the primary constituent.

Fig. 2.—General characteristics of voltage-current density relationship in typical electropolishing bath.



The theory of electropolishing and brightening does not completely explain all phenomena observed, but the following appears to be the main mechanism involved. Polishing will only take place provided the electrolyte fulfils several requirements, and only within a certain range of conditions. The electrolyte must contain an acid or base which will combine with the metal and thus cause its dissolution, but it must also contain an oxidizing agent which itself will be reduced by its reaction with the metal, and a substance capable of dissolving the oxide film.

The conditions under which polishing occurs can be determined by studying the flow of current in a cell, of which the metal to be polished is the anode, over a range of voltages.

The curves shown in Fig. 1 were those obtained by Plateau and his co-workers[4] using Jacquet's mixture of 345 ml. perchloric acid and 655 ml. acetic anhydride with a super-purity aluminium specimen 5 mm. dia. × 15 mm. long as anode, plotting the current passing for varying voltages over a period of time.

It is over the flat portion of these curves that the best polishing conditions exist. In particular, it can be seen that above 40 volts there is little possibility of polishing taking place. The point of contrast is not clear. If a curve is plotted of voltage against current with a polishing electrolyte it will take the form shown in Fig. 2. There are three portions, the first steeply-rising portion in which etching occurs, then an almost flat portion which represents polishing conditions, followed by a second steeply-rising portion where gas is evolved, with attack on the metal. In other words there is a limited range of current density and voltage required for polishing to occur. Similar features have been reported in the electropolishing of copper in a phosphoric-acid electrolyte[5].

The surface of any metal, even after mechanical polishing, is not smooth but consists of a series of peaks and troughs. As the current tends to leave the metal surface in a direction normal to the tangent of that point in the surface, current density is higher on the peaks than in the troughs. In Fig. 3 showing these conditions, the distance between the lines indicates the varying density of current emerging from the surface, by comparison with the uniform density in the body of the metal.

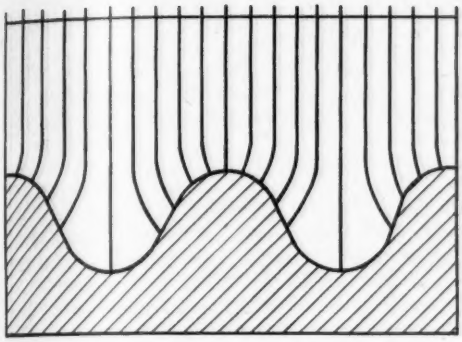


Fig. 3.—Distribution of current on uneven metal surface during electropolishing. The distance between the lines represents the current density.

When a specimen is connected to the anode of an appropriate polishing bath, and the correct current density is applied, the specimen quickly acquires a thin oxide film. According to Hoar and Mowat[41] the metal ions pass from the metal surface into vacant sites in the oxide lattice, the oxide dissolving as quickly as it is formed on the metal. The random distribution of the vacant sites would account for the absence of etch figures. At the same time the oxide film is covered by a viscous layer, probably containing Debye-Huckell complexes, resulting from the gradual solution of the metal. This layer is thinner on the peaks than in the troughs and correspondingly the oxide film is also thinner on the peaks thus facilitating the outward diffusion of metal salts.

This mechanism results in the high spots of the metal being smoothed in preference to the troughs in the surface. However, where the troughs are facing downwards in the bath there will be a tendency for them to be preferentially attacked, because salts then tend to accumulate near the edges of the grooves, thus decreasing the attack on the peaks, as would be expected from this mechanism. The rate of polishing will depend upon the concentration gradient existing between the viscous layer and the solution, and on the degree of agitation.

It has been observed that apart from the above mechanism which is called macropolishing, there can occur micropolishing—and this is primarily responsible for brightening. The work of Plateau and others[4] showed that macropolishing was only effective with their electrolyte for irregularities of 0.15 mm (0.006 in.) depth upwards. At the same time, however, micropolishing was observed which produced increased brightness due to the elimination of small surface imperfections less than 0.015 mm.

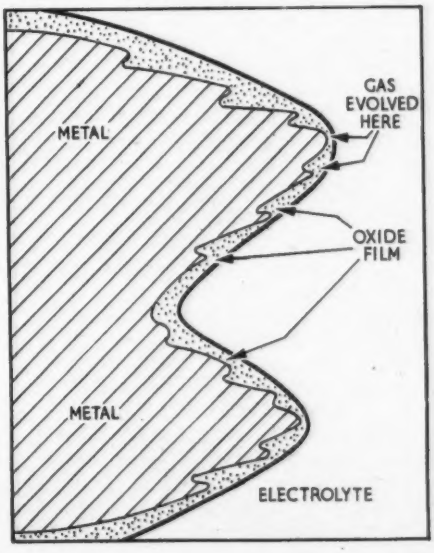
It has been suggested by several workers that micropolishing proceeds by the diffusion of aluminium ions at the small peaks in the surface through the oxide film, which is locally thinner at these points which are also of slightly higher potential. (Fig. 4.)

This mechanism is probably facilitated by the continuous dissolution and reforming of the oxide film. Micropolishing proceeds in the absence of the viscous layer associated with macropolishing and is effective for discontinuities smaller in dimensions than the thickness of the oxide film. The above mechanism is in accordance with the views of Jacquet[6] in explaining the mechanism of the Brytal and Alzak baths. Micropolishing, therefore, is primarily responsible for brightening.

Theory of Chemical Polishing and Brightening

Chemical polishing and brightening may be considered as an extension of the same principles, but with the current generated internally in the system and not externally. Under many conditions of chemical attack the grain boundaries are first attacked and then the rest of the surface—but no polishing occurs. Alternatively the flowed metal layer may be removed, and grains exposed at different levels depending upon orientation; these are subsequently smoothed by chemical polishing. For polishing to be obtained, the metal surface must be protected in the early stages by partial passivation of the surface, such as the formation of an oxide film: given a high

Fig. 4.—Diagram illustrating micropolishing.



internal current density this can be achieved. A high cell voltage is also necessary to produce polishing and this can be brought about either by raising the temperature, thus increasing the degree of attack, incorporating oxidizing agents having a depolarizing effect, or incorporating a heavy metal salt, thus forming a local couple on the aluminium surface. Often these methods are used in conjunction.

The acids most frequently used are phosphoric and sulphuric although others such as acetic, oxalic and hydrofluoric acid may be incorporated: the oxidizing-reducing system may be improved with nitric- or chromic-acid additions. The presence of copper or heavy-metal salt is not essential for polishing, and later it is suggested that the function of the heavy-metal salt is that of a brightening agent. In the simple chemical polishing solutions it appears that the hydrogen evolved acts as the local cathode, although heavy-metal salts in small amounts probably fulfill the same function.

Chemical polishing occurs in much the same manner as electrolytic polishing. When initially placed in the solution the metal reacts to form a thin, semi-permeable oxide film, and hydrogen is also evolved. A viscous layer of reaction products may also be formed, especially in phosphoric-acid mixtures, but both this layer and the oxide film are thinner at the peaks and thus attack is favoured on the high spots. The cathode is presumably provided by hydrogen retained on the oxide film in the valleys.

The effect of heavy-metal salts in the solution may be to provide brightening by the removal of local discontinuities in the surface which are of dimensions similar to that of the oxide film. The copper atoms are deposits in the valleys—points of lower potential which act as local cathodes and cause the removal by preferential attack of small imperfections in the neighbourhood. Whereas the presence of a layer of reaction complexes is necessary for macropolishing, it is not essential to brightening.

Patent literature[7] indicates that a heavy-metal salt addition to phosphoric-acid-based solutions increases brightness. It has been suggested that its function is that of a catalyst but no published information exists to support this contention. On the other hand brightening is also brought about by the addition of copper salts to an aqueous bath containing nitric acid, chromic acid, ammonium bifluoride and glycerine in which the total of added agents does not normally exceed 7 per cent. This solution would hardly be expected to produce a viscous layer of any magnitude, which suggests that in this case at least the copper facilitates brightening by micropolishing.

One of the few studies of chemical polishing[39] compared the changes produced in the surface condition of specimens of pure aluminium after various times of immersion in three commercial chemical polishing solutions with those occurring in an electrolytic bath. In the latter process the initial rounding-off of the surface projections coincides with a well-defined almost regular attack. The roughness thus produced developed further, but it was subsequently replaced by a new smoothing process which then produced a smooth, almost level, surface after 10-minutes treatment.

With both the acid (Alupol III) and alkaline (Alupol I) processes of Vernal S.A. the projections were rounded and preferential attack occurred on some crystal faces. As polishing proceeded the projections were first eliminated and then the grain-boundaries finally disappeared. On the other hand, specimens treated by the V.A.W. process (nitric-bifluoride bath) behaved rather similarly to those polished electrolytically, since smoothing combined with a corrosive attack was observed in the initial stages followed by further smoothing. The appearance of corrosions pattern in the early stages of polishing is probably due to the protective oxide film not having established itself.

A paper by H. Fischer[43] has described studies of the behaviour of aqueous and concentrated acids on aluminium. When chemical polishing was produced there were no etch patterns on the metal surface. The effect and type of etching by various media was found to be associated with local cell corrosion, current density and the nature of the anions present. High corrosion current densities, of the order of 10^{-2} to 10^{-1} amp per sq. cm. bring into play the secondary formation of hydroxide at the local anode. At the high current densities of chemical polishing—of the order of 4×10^{-1} amp per sq. cm.—a cohesive porous surface film of aluminium hydroxide must therefore form on the aluminium surface. As aluminium will only dissolve statistically at the already existing pores of the film, no etch figures are formed. This conclusion is in agreement with the views of Hoar and Mowat[41] already mentioned.

Industrial Electrolytic Polishing and Brightening Process

The processes described below are the subject of patents which are listed in the references quoted at the end of this article. The information is not intended to provide full details of the

operation of the processes, and users should note that the publication of this information in no way protects them from any action for infringement of a valid patent. The object of review in these processes is to classify the main types of polishing baths and their possible merits.

1. Electropolishing Baths

(a) *Phosphoric-acid-based Electrolytes.*

A patent[8] taken out in 1944 was based on a phosphoric-acid electrolyte to which a glycol compound or a glycol ether has been added. The composition range claimed was:—

	Preferred per cent	*Range per cent*
Phosphoric acid ...	50 to 60	(40 to 75) by weight
Water	12 „ 15	(10 „ 25) „ „
Glycol compound	25 „ 27	(15 „ 30) „ „

Temp. 75°C. (40 to 100°C.)
C.D. 100 to 300 amp. per sq. ft.
Voltage 15 to 40

When the work is so treated, a chrome-phosphoric desmudging dip is necessary after polishing and before anodizing. Subsequent extension of this type of bath are contained in patents by Alcoa[9] and by High Duty Alloys Ltd.,[10] utilizing phosphoric-acid electrolytes to which the first case glycerol and water have been added and second by a substituted carbonyl such as *n*-butyl alcohol or amyl alcohol. These long-chain compounds act as inhibitors and reduce the tendency to pitting in certain conditions. The nominal compositions of the main electropolishing and brightening baths are summarized in Table I.

None of the above baths are suitable for alloys, these require additions of agents with more powerful dissolving or oxidizing properties. One of the most common additions is sulphuric acid. A bath of this kind, which is essentially an extension of the earlier patent by Windsor-Bowen, is covered in a United Anodizing Co. Ltd. patent[11]. A typical composition is:—

	By Vol.
Phosphoric acid (S.G.1.72)	50 per cent
Sulphuric acid (S.G.1.84)	15 „ „
"Cellosolve"	15 „ „
Water	20 „ „

Conditions

Temp. 65 to 70°C. (150 to 160°F.)
C.D. 35 to 40 amp. per sq. ft.
Voltage up to 35

It is understood that this bath is in commercial use and is fairly satisfactory on Duralumin-type and magnesium-containing alloys. Adequate agitation of the electrolyte of the phosphoric-sulphuric-acid/water type is covered by a Battelle Memorial Institute patent[12] although it is mainly claimed for use on other metals. A modification of this bath patented subsequently incorporates an oxidizing agent, for use with alloys in which the silicon content does not exceed around 1 per cent. The composition[13] quoted is:—

	Preferred Composition By Weight	*Range By Weight*
Phosphoric acid ...	75 per cent	40 to 80 per cent
Sulphuric acid ...	5 „ „	4 to 45 „ „
Chromic acid ...	7 „ „	0.2 per cent upwards
Water	13 „ „	Balance

Conditions

Temp. 70 to 90°C.
C.D. 100 to 250 amp. per sq. ft.
Voltage 5 to 28 volts

It is understood that this patent forms the basis for a process being utilized in this country, although its main use has been on stainless steel.

A more recent patent by Rolls-Royce[14] covers a phosphoric-chromic-acid/water electrolyte for the polishing of alloys, while the French Company, Alias, Froges et Camargue, have patented[16] a phosphoric-acid mixture to which boric and oxalic acid have been added to an aqueous phosphoric-acid solution. It is claimed that the presence of 0.5 to 2 gm. per l. of a lead salt assists the process, and that both polishing and brightening are achieved on the metal and on its alloys.

(b) *Sulphuric-acid-based Electrolytes.*

As indicated above mixtures of phosphoric and sulphuric acid are utilized for electropolishing and are rather superior to those with phosphoric acid alone. However, there is evidence to suggest that mixtures rich in sulphuric acid but with phosphoric acid still present may have some practical application. A patent[15] by the French companies, Procol and Tréfileries et Laminoirs du Havre, covers a bath consisting nominally of 70 per cent sulphuric acid, 15 per cent phosphoric acid and 15 per cent water by volume, using a current density of 10 to 15 amp per sq. dm. (90 to 140 per sq. ft.) and a temperature of 85°C. A United Anodizing Company patent utilizes a sulphuric-acid/water/glycerine mixture ("Cellosolve" may be used instead of glycerine) which requires dipping in a desmudging solution before anodizing. The sulphuric-acid-based solutions give lower reflectivities on high-purity aluminium than the phosphoric-acid baths.

A further solution, based on sulphuric acid but with an addition of an oxidizing agent, has been patented by M. Damien S.A.[17] and has been used commercially in their Paris works. It

consists of 60 per cent sulphuric acid and 40 per cent water to which 20 gm. per 1. of sodium dichromate has been added. A high current density (several hundred amp. per sq. ft.) is used but the treatment time is only 2 to 5 min. This solution is mainly used on reflector-quality material.

An electropolishing bath based on oxidizing agents is contained in a patent[16] by the French Company, Alias, Froges et Camargue utilizing a bath containing nominally 40 per cent nitric acid, 40 per cent water, 15 per cent phosphoric acid and 5 per cent chromic acid. It is used at room temperature (10 to 20°C. at 175 to 350 amps per sq. ft. at 3 to 7 volts). No information is available on its commercial usage.

2. Electrobrightening Baths

The two established processes are Alzak and Brytal, both of which are two-stage treatments. The former method[18] utilizes a 2.5 per cent fluoboric-acid solution at 30°C. and a current density of 10 to 20 amp per sq. ft. at about 30 volts. The "smudge" film produced by this treatment is normally removed in an alkali carbonate-chromate solution[19]. A brightening bath based on a 10 per cent chromic-/1 per cent hydrofluoric-acid mixture at 55°C. using 50 amp. per sq. ft. for about 10 min. has also been proposed[20], and a further suggestion is a 25 per cent sulphuric-/2 per cent hydrofluoric-acid mixture at 60°C. and 90 amp per sq. ft.[21]. The final treatment involves anodizing in a 7 per cent (by vol.) solution of sulphuric acid at about 12 amp per sq. ft. and 20 volts. The original process is, however, most generally used because it operates at only a little above room temperature and the current required is lower than for the other mixtures mentioned. A lead- or rubber-lined tank is required.

The Brytal process[22] is alkaline, consisting of 15 per cent sodium carbonate and 5 per cent

(*continued in page 271*)

TABLE I

Electropolishing and brightening baths

Phosphoric-acid-based Electrolytes

(1) Alcoa bath		(2) Alzak bath		(3) Batelle bath	
	volume		*volume*		*volume*
Phosphoric acid ...	35 to 45%	Phosphoric acid	50%	Phosphoric acid	75%
Glycerine	30 to 40%	Sulphuric acid	15%	Sulphuric acid	5%
Water	20 to 40%	Water	20%	Chromic acid	7%
Temp. 70 to 80°C.		Cellosolve	15%	Water	13%
C.D. 150 to 275 amp per sq. ft.		Temp. 65 to 70°C.		Temp. 80°C.	
Voltage 20 to 60		C.D. 35 to 40 amp per sq. ft.		C.D. 100 to 150 amp per sq. ft.	
		Voltage 35 max.		Voltage up to 28 volts	

Sulphuric-acid-based electrolytes

(1) Procol bath		(2) Alzak bath		(3) M. Damien S.A.	
	volume		*volume*		*volume*
Sulphuric acid	70%	Sulphuric acid	50%	Sulphuric acid	60%
Phosphoric acid	15%	Water	20%	Water	40%
Water	15%	Glycerine (or "Cellosolve") ...	30%	Sodium dichromate	20 gm. per l.
Temp. 85°C.		Temp. 60°C.		C.D. 200 to 400 amp per sq. ft.	
C.D. 90 to 140 amp per sq. ft.		C.D. 75 amp per sq. ft.			
		Voltage 30 to 35			

Electrobrightening baths

(1) Brytal		(2) Alzak		(3) Soc. des Produits Chemiques	
	weight		*weight*	Aluminium phosphate ...	60 gm. per l.
Sodium carbonate ...	15%	Fluoboric acid	2.5%	Sodium hydroxide ...	100 gm. per l.
Trisodium phosphate ...	5%	Water	rem.	Temp. 80°C.	
Water	rem.	Temp. 30°C.		C.D. 50 amp per sq. ft.	
Temp. 80°C.		C.D. 10 to 20 amp per sq. ft.			
C.D. 25 to 30 amp per sq. ft.		Voltage 15 to 30			
Voltage 10 to 14					

THE PROPERTIES and ENGINEERING APPLICATIONS of ELECTRODEPOSITS

A Paper contributed to a Symposium on "The Structure of Electrodeposits" organized by the Department of Industrial Metallurgy at Birmingham University on March 15, 1955

by R. A. F. HAMMOND B.Sc., A.R.C.S., F.R.I.C.

(*Concluded from page 198, May, 1955*)

Effect of Electrodeposited Coatings on the Mechanical Properties of Steel

(*a*) *Tensile Properties*

Hard-chromium deposits are usually so thin that their influence on the static tensile strength of the component can usually be ignored. In any case the chromium deposit is brittle and liable to contain cracks so that it would be unwise to rely upon any strength increment even with the thickest deposits employed.

In heavy nickel work, however, the thickness of the nickel may sometimes constitute a sensible proportion of the cross-section of the component and the question of the overall strength of the repaired article then arises.

Table III gives the results of tensile tests on standard test-pieces to B.S. Spec. No. 5005 made undersize, built up with nickel and machined back to standard size in such a way that 20 per cent of the final cross-sectional area was of nickel.

It is apparent that a sound adherent coating adds to the tensile properties of the base to which it is applied in proportion to its thickness and its properties relative to those of the base. The ductility of both hard and soft steels is increased by the soft deposit and the ultimate tensile strength of a hard steel is reduced and of a soft steel increased by the hard deposit.

Fatigue Strength

That the fatigue strength of metals may be diminished by electroplating has long been known. The effect is particularly well marked with nickel and chromium and the fatigue limit of a high-tensile steel, for example, may be reduced by 60 per cent or more.

As this effect is closely associated with internal stress in the electrodeposit a few words on this subject will be appropriate. Most electrodeposited metals undergo a change in volume after they have been deposited which sets up internal stress in the deposit. In general the stress is tensile but some deposits, notably zinc and lead, show a compressive stress. Nickel and chromium are normally strongly tensile but certain "bright nickel" deposits exhibit a slight compressive stress.

The tensile stress in nickel and chromium varies very considerably according to the composition of the solution and the conditions of

TABLE III

Effect upon Tensile Properties of Steel of replacing a Portion of the Cross-Sectional Area with Electrodeposited Nickel : Average results
(*After Hothersall, Proc. Inst. Mech. Eng.* 1945. *Vol.* 152)

Core metal		Nickel deposit		Tensile Properties	
Description	Hardness D.P.H.	Description	Hardness D.P.H.	U.T.S. (tons per sq. in.)	Elongation (per cent)
Mild steel	183	None	—	42.0	14.0
" "	"	Soft	170	39.7	18.0
" "	"	Hard	280	44.8	12.5
Nickel-chromium steel, hardened	286	None	—	63.0	18.7
and tempered	"	Soft	194	56.5	20.4
B.S.S.5005/501	"	Hard	315	58.5	9.8

deposition, but under abnormal conditions the stress in nickel deposits may reach a sufficiently high value to cause spontaneous fracture of the coating and normal chromium deposits contain internal cracks which are the result of stress relief.

In spite of the high internal stress in these deposits it is only rarely that this property introduces practical difficulties in engineering applications, *e.g.*: (a) in electroformed nickel or copper articles, *e.g.* electrotypes or wave-guides the stress may cause distortion; (b) similarly deposition of a thick nickel coating on an article of thin section may cause distortion of the article; or (c) heavy nickel or hard-chromium deposition on a high-tensile steel component may lead to a considerable drop in the fatigue strength. This could have serious consequences if the part is subjected to critical alternating stresses in service, *e.g.* in an aircraft.

A general connexion between stress and the loss in fatigue strength of the basis-metal has long been known to exist. For example *Barklie and Davies* showed many years ago that the use of superimposed a.c. on d.c. in nickel-plating both reduced the internal stress in the deposit and diminished the loss in fatigue strength. They also showed that the deposition of a thin lead undercoat reduced the loss in fatigue-strength of steel caused by nickel-plating from 28 to 7½ per cent.

In a recent investigation in A.R.D.E. on the effect of chromium-plating on the fatigue-strength of steel a linear relationship has been established between the magnitude and direction of internal stress and the percentage loss of fatigue-strength. The importance of low stress in a nickel- or chromium-plating solution is thus obvious.

After hard-chromium plating the components are sometimes low-temperature heat-treated with the object of eliminating hydrogen embrittlement and this may be called for in the specification. It is important to appreciate that such heat-treatment will produce a further lowering of the fatigue strength of the component. Some years ago *Logan* and other investigators found that l.t.t. in the range 150 to 300°C produced an additional marked reduction in the fatigue-limit as compared with the "as plated" value, which itself might be 40 or 50 per cent below the fatigue-limit of the unplated steel. Logan also showed that heat-treatment at 440°C largely restored the fatigue-limit to the "as plated" value and recent work in A.R.D.E. has confirmed this result.

It will thus be apparent that components subject to critical alternating stressing in service should preferably be heat-treated after plating in the range 400 to 500°C and that, if by reason of the effect of annealing at this temperature upon the mechanical properties of the steel or on the hardness of the chromium, treatment at this temperature cannot be tolerated, it would be best for such components if heat-treatment were omitted altogether.

TABLE IV

Effect of Heat-Treatment on the Hardness of Electrodeposited Chromium

Condition	D.P.H.
„ as deposited	800-900
Ht. tr. 200°C.	small drop
„ „ 400°C.	> 650
„ „ 600°C.	420
„ „ 800°C.	250

As shown in Table IV, l.t.t. in the range 400 to 500°C produces an appreciable drop in the hardness of the chromium but for many purposes the residual hardness of, say, 600 to 700 D.P.H. will be adequate.

Methods of Countering Fatigue Strength Loss on Plating

It will be of interest now briefly to consider possible methods of overcoming the effect of plating in reducing the fatigue-strength. Since internal stress in the electrodeposit is the primary cause of loss of endurance of plated components, reduction in the internal stress of the electrodeposit is the most obvious line of approach to this problem. It should be possible in fact actually to increase the fatigue-limit of the plated component by applying a deposit with residual compressive stress and *Almen* has proposed the use of "bright nickel" solutions giving a deposit with compressive stress for heavy nickel work and has demonstrated the improved fatigue strength in laboratory tests. Whether such fine-grained and brittle deposits would be suitable for many such applications is open to question.

Almen also states that since high yield-strength and high-hardness are desirable in a deposit to be used for engineering purposes, chromium would be superior to nickel for rebuilding if it could be plated "in a state of high residual compression together with a high bond-strength." Compressively stressed chromium has recently been reported in the literature and we also have recently found that chromium can be deposited from a standard solution in a state of zero or slightly compressive stress by controlling the temperature although the practical possibilities have not yet been explored. It may well be therefore that *Almen's* suggestion which

seemed wishful thinking when it was published a few years ago may before long be realized in practice.

An alternative to eliminating or reversing the stress in the electrodeposit is to induce a compressive stress either in the deposit after plating or in the base before plating. Shot peening, superficial rolling, or nitriding the steel base or similar mechanical processes on the deposit (if nickel) have been shown to be effective.

It is clear from what has been said that the effect of plating on the fatigue-limit is too important a factor to overlook and may indeed be of critical importance especially in aircraft applications. Nevertheless, it should be appreciated that most of the published evidence is based upon reverse-bend laboratory tests which are designed to break the specimen. Such levels of alternating stressing are seldom met with in practice and in fact cases of fatigue-failure clearly attributable to nickel or chromium-plating are extremely rare. The situation therefore does not justify any general condemnation of heavy nickel or hard-chromium plating on grounds of endurance loss.

Summary

In this brief review an attempt has been made to show that by electrodeposition it is possible to apply sound thick coatings of metal which are strongly adherent to the basis-metal and of which the mechanical properties are susceptible of control and are not, in general, inferior and may be superior to those of the basis-steel.

The processes of heavy nickel and hard-chromium plating which are the most common examples of this application of electrodeposition have not been much publicized but have made an important contribution to engineering industry for over a quarter of a century and new applications of thick electrodeposition and allied processes are constantly coming forward.

DISCUSSION

DR. J. E. GARSIDE (Northampton Polytechnic, London) said he was very interested in the comments which Mr. Hammond had made on the subject of strength, but was a little worried about the question of tensile strength and shear strength and would be grateful for an expression of opinion on that. He appreciated that tensile strength was important, but the opinion was widely held that shear strength was also important. He knew how difficult it was to measure shear strength on electrodeposits. He thought that the Ollard test, if carried out properly, measured primarily tensile strength, and he gathered that the figures for strength which Mr. Hammond had quoted were for the tensile strength. It would be interesting to have an opinion on how far shear strength came in.

He was also very interested in the comments which Mr. Hammond made on hardness, and he wondered whether or not some of the hardness ranges to which Mr. Hammond had referred might not be due to mixed crystalline forms.

Mr. R. A. F. HAMMOND, said in reply, that although the quantitative results which he had given were based on the application of a tensile force and were in fact measurements of the tensile strength of the nickel, it was true that failure could occur by shear of the nickel. It would be recalled that the Ollard test made use of a test-piece in which a thick deposit was plated on the top of a cylindrical test-piece, and after deposition the deposit was drilled through—this should, perhaps, be described as a modification of the Ollard test—and the nickel deposit was machined flush with the end of the test-piece. The basis metal and the deposit were then separated by forcing the base away from the deposit while the deposit was supported in a heavy steel ring. In fact in their experience the failure occurred, when the deposition was good, by a shear of the deposit through its thickness.

In recent years they had used another form of tensile test which was described as the Bullough-Gardam test, in which the test-piece took the form of a steel shank with a taper on the end and a steel cap which was very accurately ground to fit the taper. The deposit was placed on the end of the cap and the shank and the cap was pulled away, stressing the interface in tension. There again they found that, when the deposition had been correct, the failure always occurred by shear of the nickel and they finished up with a piece of nickel still adhering to the steel shank. In fact, therefore, they were measuring the shear strength of the deposit, although it was true that they calculated on the basis of the cross-sectional area of the spigot end, or of the annulus with the Ollard test. To that extent they had perhaps made a mistake in describing their results as the results of tensile tests.

He thought, that there was a well-recognized correlation between the shear strength and the tensile strength of a metal, and, there was nothing to suggest that that same general relationship would not hold in electrodeposits.

On the question of the cause of hardness, and Dr. Garside's suggestion that hydrogen absorption might be a cause of the abnormal hardness of electrodeposits. Mr. Hammond did not think that there was anything to support that suggestion. The relationship between the acidity of a nickel

bath and the hardness of the nickel deposit showed that the softest deposits were obtained at the low end of the *p*H scale. Furthermore, the softest deposits were produced when the maximum percentage of hydrogen was discharged. He did not think, therefore, that there was any relation, in nickel deposits at any rate, between the hydrogen discharge and the hardness of the deposit. He believed that the factor which most determined hardness was, in the case of normal good practice, with good, uncontaminated solutions, the codeposition of basic material at the cathode surface, its absorption on the crystal facets of the growing crystals, thus inhibiting grain growth and favouring fresh nucleation, and the consequent building up of a very fine structure with an adsorbed film on each grain which tended to prevent slip between adjacent grains and thus give the effect of hardness.

He was not able to comment on the possibility of mixed crystalline forms affecting the hardness.

Dr. D. N. LAYTON said that in his opinion mixed crystalline forms had a lot to do with hardness, although he could not explain the exact correlation. In general the smaller the grain size the harder the deposit. At the high temperatures which had been postulated at the cathode layer there might be some re-crystallization provided there was not too much co-deposited material. If however, there was much co-deposited material, then, although the re-crystallization temperature might be reached, grain growth would be impeded so that hard deposits could still occur.

Mr. E. A. OLLARD (British Non-Ferrous Metals Research Association) said that he was interested to note that Mr. Hammond had specified an uncontaminated solution. He would like to ask what an uncontaminated solution really was. Some work had been done recently which was of interest in this respect. The average person doing plating would never consider that a nickel solution was contaminated if it contained 25 p.p.m. of copper. The work to which he referred showed, however, that if the copper were reduced to something below 1 p.p.m., which was not easy but could be done, many things which normally happened with a nickel deposit did not happen. He thought that in future when talking about these solutions it would be desirable to say what they really were. It was no use saying simply so much nickel sulphate and boric acid; they ought to know the iron, copper, zinc and any organics present, and how much of them there was.

Mr. H. E. SMITH (B.S.A. Group Research Centre), taking the question of bath impurities a stage further, asked whether any suggestions could be put forward as to the mechanism by which the addition of very small amounts of a manganese salt to an iron plating solution radically altered the structure and physical properties of the deposit.

Dr. D. N. LAYTON replied that if there was put in the solution a small quantity of something which was co-deposited and incorporated in the crystal lattice one might block up dislocations and so on which prevented the deformation of crystals. It was well known that a minute trace of foreign material in the crystal lattice could produce an enormous effect on the specific characteristics.

Mr. SMITH mentioned that chemical and spectrographic analysis showed that no manganese was present in the deposit.

Dr. LAYTON said he would have thought that if there had been enough there to be effective it would show up spectrographically; but, of course, additions to solutions might affect the actual solution composition next to the cathode surface, and that alone might affect the axiometric growth of the crystal to some extent. The answer might be, therefore, that it was not incorporated but it did modify the solution, or else that it was incorporated but the experimental technique employed was not such as to detect it.

Mr. HAMMOND said he was not at all surprised at the result, and did not think that it was necessarily to be expected that it would be possible to detect anything in the deposit. He had in mind some work done by himself and others many years ago in which they studied the effect of various changes in the composition of nickel-depositing solutions on the structure and properties of the nickel deposit obtained. They took a standard Watts bath and then altered the composition in a systematic way by taking away individual elements and doing deposition experiments with the bath which resulted, and they found that, for example, if they omitted the potassium or sodium from the bath—it had a marked effect in altering the crystal size and hardness of the resulting nickel deposit. Similarly, by eliminating chloride ions from the solution quite a marked effect was obtained on the physical and mechanical properties of the electrodeposit. Those ions were not deposited in any case, but they had a marked effect on the structure of the nickel deposit. Their interpretation of the effect of those ions was that they modified the physical condition and amount of the basic material produced by hydrolysis in the cathode film, thereby favouring or inhibiting the production of colloidal material which could be incorporated in the deposit, thus affecting its structure.

NUMBER FOUR

METAL FINISHING RESEARCH
A Survey of its Organization, Existing Facilities and Current Work

Metal Finishing Research at Aluminium Laboratories Limited, Banbury

SINCE the war there has been a vast expansion in the civilian uses of aluminium and a noteworthy feature of this increase is the number of new uses in which surface appearance and behaviour are of paramount importance. In the building and automobile industries, for example, large quantities of the metal are being used for decorative trim where good appearance over a long period is essential. Again, in packaging, aluminium appears in contact with a great variety of substances and is required to provide protection without interaction.

These new uses have given rise to many queries, particularly concerning the behaviour of aluminium in contact with other materials, and the answers are not always available. The surface conditions of the metal and its changes with time are often of predominant importance and there is a widespread need for information on this aspect of aluminium technology. It thus comes about that these newer applications have stimulated research and development work on all phases of metal finishing applied to aluminium.

In the Aluminium Limited group, such investigations are being carried out by Aluminium Laboratories Limited at Kingston, Ontario and Banbury. The present description refers specifically to the work at Banbury and to the new plant installed in the recent extensions to the premises (see *Sheet Metal Industries*, June 1954).

The technical problems are partly fundamental and partly a matter of development of existing knowledge. On the fundamental side it should be realised that aluminium itself is a very reactive metal, as can be shown by the behaviour of the amalgamated metal which will oxidize continously in air or decompose water. In this case the presence of the liquid mercury prevents the re-formation of the protective film which normally forms automatically and protects the naked metal. Thus the whole resistance of aluminium depends on the oxide film and it is therefore essential to know as much as possible about it. The paradoxical combination of a hard, brittle, glassy, non-conducting chemically inert oxide film on a relatively soft, ductile, electrically and thermally conducting metal produces conditions which make it unsafe to generalize about the behaviour in untried circumstances. Thus fundamental work on the oxide film proceeds: for example, on its rate of growth in air or other gases at elevated temperatures, on the effect of various alloying elements, and on the cause of the modified electrolytic solution potential of the metal which is brought about by dissolution or dispersal by specific ranges of acidity or alkalinity or by specific chemicals. All this is physical chemistry of a fundamental kind and the techniques employed are similar to those in other fields of physical chemistry. For this the resources of the Chemistry Division, supplemented by those of the Physics Division are well equipped. The physical work extends into electrochemical fields but also, where appearance is in question, into optical measurements, for which a Guild reflectometer and an Eel spectrophotometer or colorimeter are available.

It has long been known that among the most satisfactory ways of enhancing the natural corrosion resistance of aluminium are chemical and electrochemical methods of thickening and reinforcing the natural oxide film. A versatile and compact metal-finishing plant has been provided for this type of work. It has been built on two principles (i) that it should be big enough to treat actual end-products rather than laboratory specimens, (ii) that it should be sufficiently flexible to change at short notice from concentration on one type of treatment to another quite different treatment, provided only both are "wet" processes.

With this end in view the plant has been built up around two rows of tanks; one set 2 ft. 6 in. long × 1 ft. 6 in. wide × 2 ft. 6 in. deep, 50 gallons capacity, the other set 2 ft. long × 1 ft. wide × 2 ft. deep, 17 gallons capacity.

The larger tanks include those permanently fitted for basic processes such as trichlorethylene-

Fig. 1.—General view of the metal-finishing shop.

vapour degreasing, caustic etching, nitric-acid dip and inhibited-alkali degreasing, with the associated rinse tanks. A sulphuric-acid anodizing tank and a chromic-acid anodizing tank, both lead lined, electrically heated, thermostatically controlled and air agitated are also permanently installed; the sulphuric tank is water cooled. These tanks and many others are exhausted through plastic ducting to a fan chamber on the roof. Two other tanks are provided with permanent low-tension current supplies, heat, draughting, etc. One of these is rubber lined and is intended for electro-brightening processes or, as at present equipped, for nickel electroplating; the other is intended for other types of electro-brightening, although it can also be used for chromium plating. The remaining tanks, most of which are equipped with heaters, air supply and ducting, and can be temporarily wired for current supply, are of various materials—but mostly stainless steel or plastic lined and are intended to be used as required for differing chemical processes such as M.B.V., Alocrom, Bonderizing, hydrofluoric-acid etching and

Fig. 2.—View of paint and lacquer testing laboratory. Right, determination of water covering area of aluminium flake pigment; left, determination of water content of paint by the Karl-Fischer method.

Fig. 3.—View of physical chemical laboratory: left, investigation of lacquers; right, electrochemical tests.

similar treatments. An aluminium tank is equipped for sealing anodized coatings in boiling water or solutions and is therefore lagged against heat loss. Another tank has been provided with a polythene lining and hot water jacket for chemical brightening by the Erftwerk process as mentioned later. Quite large articles can be treated and a two-hundredweight capacity monorail is installed over this row of tanks to allow handling of heavy articles. An electrically heated drying or lacquer-stoving oven is also accommodated in this shop.

The smaller tanks are mostly made of stainless steel with electrical thermostatically controlled heating and plastic ducting. They are intended for varied use with strongly acid mixtures for chemical brightening or satin etching or for dyeing.

A motor generator set of 250 amp. capacity and infinitely variable voltage up to 60 volts is housed in a separate room. This relatively high voltage for electrochemical processes is necessitated by the requirements of the chromic-acid anodizing process. The voltage of the supply can

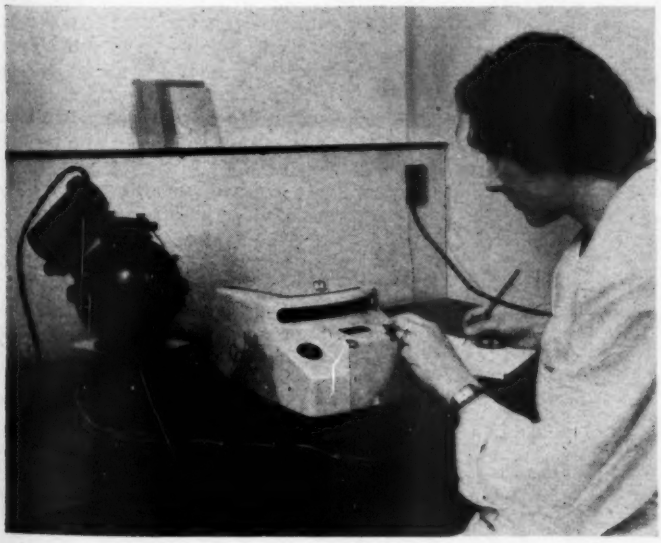


Fig. 4.—Measuring the total, specular and diffuse reflectivity of chemically brightened aluminium sheet on the Guild Reflectometer (as specified in BS. 1615.).

be controlled from several alternative working positions by means of "raise" or "lower" push buttons, but each tank which is permanently equipped for current supply has its individual switchboard with double-pole knife switch, double-range ammeter and voltmeter. The floor and walls are tiled in acid-resisting impervious bricks jointed with special cement and the room is drained by two longitudinal gulleys so that it can be hosed down. In an adjoining room, with dust-proof door, there is a polishing spindle with dust-extraction equipment of the air-recirculating type, and also a bench with usual services, for control tests and shop analysis.

In spite of the profusion of fixed tanks, some room can be made available for improvised plant and thus it has been possible, for example, to

Fig. 5.—Preparing standard paint spray samples. The panel is mechanically traversed past the spray gun.

treat the component sheets of two aluminium houses with either of two chemical treatments designed to obviate glare while retaining the advantageous radiant-heat-reflecting properties of aluminium building sheet. Similarly, washing machine tubs and other bulky pieces have been anodized with improvised gear.

The large quantites of pure water required in all this work are obtained from a portable ion-exchange apparatus.

It may be appropriate here to say a few words about the relative interest in the various wet processes of protecting and embellishing aluminium alloys. The well-established Bengough-Stuart process of anodizing in chromic acid remains useful for corrosion protection *per se*, and is also used for flaw detection. It is often not realised, however, that chromic acid solutions can be used at other current voltages and concentrations than those laid down for the Bengough-Stuart process to produce anodized films of interesting properties, *e.g.* opaque films which alone, or when dyed, simulate vitreous enamel coatings. The sulphuric-acid anodizing is chiefly carried out on conventional lines, but there is some interest in very rapid anodizing as for containers or hollow-ware, and low-voltage alternating current is therefore sometimes employed. As is well known, the simpler and purer alloys provide the more transparent and colourless films. Super-purity aluminium or its magnesium alloys anodize to give totally transparent and thus invisible films. It is this, rather than their chemical-brightening properties, which usually dictates the use of super-purity based alloys for special brightened and anodized treatments, *e.g.* for jewellery or in competition with chromium-plated heavy metals.

The purely chemical oxide or metal conversion coatings such as M.B.V., phosphating or chromating are chiefly required as pretreatments for lacquers or paints but are becoming less essential as paint chemistry improves and intrinsically adherent paints and lacquers become available. Nickel and chromium plating of aluminium has been a subject of much study for many years. At present the chemical zincate or electrolytic zincate (Vogt) process is considered best and electroplating of aluminium is sometimes required, but usually equal or better appearance and resistance can be obtained by the chemical or electro-brightening processes. The aluminium industry itself is indeed doubtful of the necessity

or wisdom of electroplating aluminium, because as good or better service can be obtained from the electro-brightened and anodized metal. In this connexion a bewildering and ever growing variety of electro-brightening and chemical-brightening processes are available. They can be divided broadly into the Alzak, Brytal, phosphoric acid and Erftwerk types. All these have been examined by Aluminium Laboratories Limited, Banbury, at one time or another and each has its own advantages. However, brightened aluminium is insufficiently tarnish resistant to withstand outdoor or moderate exposure permanently without the additional protection of an anodized coating.

In some applications an attractive colour tone or a simulation of gold is required which can best be achieved by the dyeing of an anodic coating. Here, only the super-purity grade of aluminium or its magnesium alloys yields a completely transparent coating which does not cloud and impair the brightness of the final result. Only the Alzak, Brytal and Erftwerk processes serve to give a truly high brilliance on super-purity aluminium and of these the first two serve principally to brighten a surface already smoothed by mechanical polishing. The Erftwerk process on the other hand will both smooth and brighten as a result of its considerable degree of attack. The finish that can be obtained on pressings of good quality sheet metal by a combination of this process and subsequent sulphuric acid anodizing has the smoothness, image clarity and tarnish resistance of mass-produced chromium plate although the operations omit mechanical polishing and are much simpler and more speedy. For this reason considerably more attention has been devoted at Banbury to this brightening process, which seems as yet almost unknown in England, than to the other more extensively publicised ones.

Fig. 6.—The differing image clarity of three samples of chemically brightened aluminium sheets is clearly shown by the reflected images of the illuminated grid, although the three samples were of similar brightness or brilliance. Brilliance of chemically brightened metal must be accompanied by good clarity of the reflected image if the finish is to be satisfying.

In spite of the attractive appearance and high corrosion resistance of aluminium there may be advantages in decorating or protecting it by the wide range of organic finishes, paints and lacquers. Many parts of domestic appliances and other consumer goods are made of aluminium for lightness or convenience but requires the fashionable stove-enamelled finish. Closures for bottles and other food containers or dry-goods packs require a hygienic, decorative and distinctly coloured or printed finish, while structural mem-

Examples of some of the effects obtainable by the use of different types of finish on various aluminium products.

bers of the stronger alloys may require a conventional protective painting scheme to maintain the full advantage of the reduced section which their lightness offers. For this reason a well-equipped laboratory for paints and lacquers is provided at Banbury which works in close collaboration, on the one hand, with a development laboratory concerned with the application of aluminium to food cans, and on the other with an experimental plant for research in the production of the widely used aluminium flake pigment.

This paint laboratory has a small exhausted spray booth, thermostatically controlled drying room, and most of the usual paint-testing apparatus. A miniature roller-coating machine and crank press are available for testing lacquers as applied to the flat sheet which is afterwards pressed and formed to shape. In this laboratory a wide variety of painting schemes or lacquer systems can be tried out, ranging on the one hand, from etch-primers for protection of strong alloy sections during the period between manufacture and fabrication of the finished structure, to, on the other hand, delicately tinted and glossy stove-enamel finishes for small goods. While the associated companies of Aluminium Laboratories Limited (for example, Northern Aluminium Company Limited in the U.K., Aluminium Union Limited, and L'Aluminium Commercial SA) do not themselves manufacture finished articles, their salesmen have to be ready and able to advise customers on finishes and to investigate difficulties, and complaints. This advice may range over a surprising field and includes such subjects as infra-red reflectivity of petrol storage tanks, ships paints and antifouling compositions, lithographic metal printing, decorative finishes on foil, laminating compositions, metal adhesives, rubber bonding preparations, etc. In all these applications the organic material is being applied, not directly to a metal, but in effect to the glassy, inert and essentially non-metallic oxide film, so that the problems are usually very different from those facing other metal fabricators.

While they are hardly a part of the metal finishing equipment, mention must be made of the facilities for corrosion testing and research, as these form an important touchstone for the selection of one finish rather than another. This work is divided to some extent into two types. Within the Metallurgical Division the corrosion behaviour of all aluminium alloys is studied under various conditions of atmospheric and service exposure. The properties of the alloys which are most often used as a measure of corrosion behaviour are the tensile properties and the characteristics of the attack as viewed under the microscope. The intercrystalline corrosion behaviour of strong alloys under stress-corrosion conditions, and the pitting behaviour of the simpler wrought alloys are obvious examples where a physical metallurgical approach can be employed with advantage. This is catered for by a suite of laboratories, including two large thermostatically controlled constant-humidity rooms, one for stress-corrosion investigations and one for intermittent or continuous salt-spray test. In a third room, immersion tests are carried out including investigation of the perplexing pitting of aluminium by mains water. This work is supplemented by exposure stations in the relatively rural district of Banbury, the industrial atmosphere of Stratford, London, E., and the marine environment of Brixham, Devon, as well as access to other sites scattered throughout the world.

The second type of corrosion testing, under the Chemical Division, consists of numerous *ad hoc* investigations directed to answering customers' or salesmen's queries as to how aluminium will behave in contact with some particular one of the multifarious natural products such as dairy materials, foodstuffs, rubber latex, crude oil, sewage, etc., or in the numerous processing industries in which aluminium is increasingly replacing the older and heavier metals. Often a good appreciation of the behaviour can be forecast from the existing literature or knowledge, but in many cases there is that little difference in the proposed application which justifies or indeed necessitates a special trial. An interesting corollary of this work is the examination of corroded specimens or corrosion products to determine the cause of failure. Usually the information available about conditions of service is inadequate or deficient in a vital particular so that the "post mortems" become detective work. The amount of sample, particularly of corrosion product, is often so small that microchemical methods of examination are necessary. It is, however, surprising what a lot of information can be obtained in this way as to the general cause of corrosion—whether due to chlorides, atmospheric-pollution acids, contact with dissimilar metals, stagnant-water pitting, etc. From this type of work very valuable experience is built up as a guide to future applications.

It will be apparent that in all these investigations, as indeed in the whole of the work described in this article, attention is concentrated on the interface between the metal and some other product or rather the sandwich made up of metal, oxide layer and product, and so the whole work can be summed up in the general title of "Surface chemistry of the aluminium /aluminium oxide complex."

A Plater at Torquay

A SHORT ACCOUNT OF THE ANNUAL CONFERENCE OF THE INSTITUTE OF METAL FINISHING

The sixth post-war residential Conference of the Institute of Metal Finishing was held this year at the Palace Hotel, Torquay, on May 17 to 21. The following report by a member of the Institute who attended the Conference, is reproduced in his own words as it serves to give an effective review of the proceedings as they appeared to one of those for whom they were organized. It does not purport to be, nor in the space available could it attempt to be a full and comprehensive report of the technical discussions.

THE Palace Hotel, Torquay, is one of the larger hotels in the country, standing in extensive grounds about two miles outside the town. As this was the first of the residential Conferences at a seaside resort organized by the I.M.F., which I had been able to attend, I was looking forward to the experience with much interest. I must confess to have wondered in the past why it was necessary to go so far away to an expensive seaside hotel in order to hold a technical Conference, when a centre like Birmingham would have seemed so much more appropriate and more accessible to the majority of the industry, but looking back on this latest Conference, I can say that the whole notion of getting away from the industrial areas and finding a hotel which can accommodate the whole Conference, is well worth while. I say the whole Conference, although in fact even the Palace Hotel was unable to accommodate everyone who turned up and it was unfortunate that quite a number of people had to be boarded out some little distance away. I suppose though that this cannot be avoided as the number of people attending these Conferences gets bigger every year and there are not many hotels in the country that can deal with such numbers.

Anyway I was one of the lucky ones and had a very pleasant room in the Hotel. All the organization seemed to be working smoothly, and soon after I arrived I registered at the Conference office where I was given all the necessary tickets and papers, together with a handsome Conference badge bearing my name. I was very pleased indeed to see that these badges were universally worn as they are a very great help in getting to know people and in helping to break the ice for newcomers. After dinner on the first evening there was a film show of some technical films which I watched for a while, but one or two of them were rather too technical for me so I took the opportunity of getting to know some of my fellow members.

The following morning we all assembled in the ballroom of the Hotel at 9.30 a.m. and with very little delay (time keeping was remarkably good all through the Conference) the Conference was declared open and all members were welcomed to Torquay by the Mayor, Councillor W. H. White.

The Chairman for the first session that morning was the President of the Institute, Professor J. W. Cuthbertson, and three papers were presented by their authors. These were " The Effect of Chromium Plating on the Fatigue Strength of Steel " by C. Williams, B.Sc., A.I.M., and R. A. F. Hammond, B.Sc., A.R.C.S., F.R.I.C., " A Study of Cracking in Chromium Deposits " by H. Fry, B.Sc., and " A New Method of Analysing the Stresses and Strains in Deposited Coatings," by H. J. Pick, Ph.D.

I am afraid that much of what was said at this session went rather over my head as most of the discussion dealt with problems of fatigue and stresses in plated coatings and required more engineering knowledge than I possess. However, such work is of undoubted value if electroplating is to continue to find increasing application for engineering purposes. It was perhaps rather a relief after some of the alarming things that had been said to hear Mr. J. W. Oswald of Fescol, Ltd., say that his company had been depositing chromium for some thirty years and could count the fatigue failures on the fingers of one hand. The few which had failed, had failed not so much because of chromium deposition as because of bad machining after chroming, leaving a notch which had caused a failure. From all that was said it certainly appears that more work is needed on both these subjects and it is far too early yet to generalize.

The afternoon session started at 2.30 p.m. with Mr. A. W. Wallbank in the chair. Three papers were presented, singly, and discussed. The first of these was " The Electrodeposition of Iron-Zinc Alloys " by Miss S. Jepson, S. Meecham, M.Sc., and F. W. Salt, Ph.D., B.Sc. This I found very interesting, as I am of the opinion that there is going to be a great deal more heard of alloy

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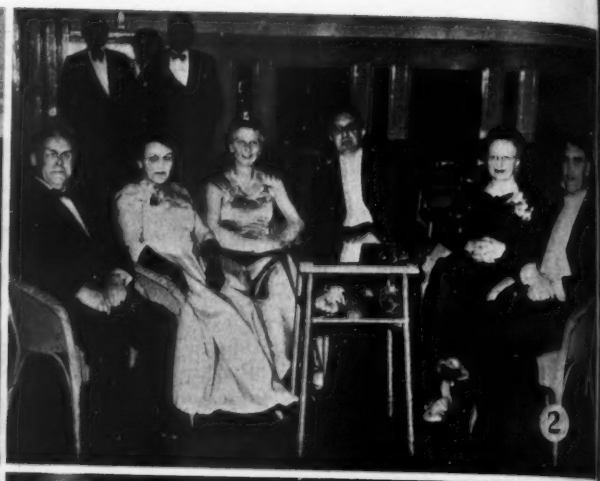
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plates in the next few years, and not only of simple binary alloys, but also of ternary and even more complex ones as well.

It was particularly interesting to hear that this alloy coating exhibited marked levelling action and Mr. R. W. Bailey of the Zinc Development Association who opened the discussion, suggested that the adhesion of paint to the alloy might well prove better than it did to zinc.

A very timely and down to earth point of view was expressed from the chair by Mr. A. W. Wallbank, who said that it was possible, if not probable, that the field of plating in the future, lay in alloy deposition. Enough had been seen with such alloys as tin-zinc and tin-nickel, to whet the appetite, but these processes would remain laboratory curiosities until and unless there was a demand for them from industry and they became practicable production processes. Any new alloy plate introduced said Mr. Wallbank, would not get very far unless it had properties not possessed by the metals which had been traditionally plated for the past twenty or thirty years.

In replying to the discussion, Dr. Salt mentioned that one advantage of the coating was that the bulky white rust which was formed as a corrosion product of zinc was modified by the inclusion of iron, decreasing as the iron content increased, until at about 70 per cent iron there was very little corrosion product in evidence.

The next paper was "Corrosion Tests of Electrodeposited Tin-Cadmium Coatings on Steel" by S. C. Britton, M.A., and R. W. de Vere Stacpoole. Discussing this Dr. S. G. Clarke, A.R.D.E., Woolwich, said that the paper was welcomed, as recently cadmium plate had become a source of worry and loss of confidence owing to the fact that it sometimes mysteriously and rapidly acquired a coating of a useless, or indeed, harmful corrosion product. This could be caused by organic vapours given off from certain insulating materials and plastics, and even worse by some kinds of wood. This state of affairs had resulted in some specifications banning the use of cadmium for parts in enclosed spaces. The improvement found with tin-cadmium alloy deposits under such conditions gave hope that this alloy coating would overcome this particular trouble. Dr. Clarke asked whether any work had been done to compare the behaviour of tin-zinc in such conditions.

Mr. S. C. Britton replying to Dr. Clarke, said that tin-zinc was rather better than zinc in resisting attack by organic vapours, but much inferior to tin-cadmium alloys.

The final paper to be presented and dicussed that afternoon was "On the Electrodeposition of Tungsten-Cobalt Alloys From Aqueous Solutions" by T. P. Hoar, M.A., Ph.D., B.Sc., F.R.I.C., F.I.M., and I. A. Bucklow, B.A. Discussion on this paper was opened by Mr. C. H. R. Gentry, Philips Electrical Ltd., who said that while the experiments described held out considerable possibilities for the eventual commercial plating of alloys with unusual and useful properties, the theoretical and fundamental considerations put forward provided some solid information which would assist towards a real understanding of the electrodeposition of alloys of the refractory metals.

He and his colleagues had done some work a few years ago on the co-deposition of tungsten with the ferrous metals and the 62 per cent tungsten content achieved in alloys with cobalt agreed remarkably well with the figures claimed in Dr. Hoar's paper. Mr. Gentry said that from the theoretical viewpoint the main interest in the electrodeposition of tungsten alloys was why such alloys could be deposited from aqueous solutions whereas pure tungsten had not so far been deposited. Although tungsten could be readily plated from fused salt baths, and it might be possible to plate it from organic solvents, he was convinced that pure tungsten could not in fact be plated from aqueous solutions. He based this opinion on two main considerations.

First, so many investigators had tried and failed. Admittedly the scientific and patent literatures contained a number of claims—frequently for very thin deposits—but they had tried to substantiate this work always without success. It seemed that the various claims for thin deposits of tungsten were due to the plating of alloys with iron or nickel, the latter derived from impurities in the chemicals used, or even possibly to corrosion products from the electrodes or their connexions.

Their own attempts to plate tungsten included what they hoped were systematic investigations

On the facing page are a number of groups of delegates photographed during the various evening social functions of the conference.

1. *Mr. and Mrs. M. L. Alkan (M. L. Alkan Ltd.).*
2. *Mr. and Mrs. F. Denison, Mr. and Mrs. J. Dawson (Ferranti Ltd.). Dr. and Mrs. J. W. Price (Tin Research Institute).*
3. *Dr. and Mrs. H. E. Zentler-Gordon (Battelle Development Co. Ltd.).*
4. *Mr. and Mrs. E. J. Flewitt (Benjamin Electric Co. Ltd.), Mr. and Mrs. F. Willetts (W. and T. Avery Ltd.).*
5. *The winner of the John Preston Golfing Trophy, Mr. H. Hope (Ionic Plating Co. Ltd.). The runner-up in the competition was Mr. John Gifford (Electro-Chemical Engineering Co. Ltd.).*
6. *Mr. and Mrs. J. A. Lowe (Westinghouse Brake and Signal Co. Ltd.), Mr. and Mrs. H. Cann (W. Canning and Co. Ltd.), Mr. and Mrs. F. Brockington (W. Canning and Co. Ltd.), Mr. P. Bang and Mr. H. K. Vengberg (Teknologisk Institut, Copenhagen).*

The Mayor of Torquay, Councillor W. H. White, is greeted by the President, Professor J. W. Cuthbertson prior to the official opening of the Conference. In attendance are (left) Mr. R. A. F. Hammond, chairman of the Conference technical sub-committee and Mr. L. S. Lowery, secretary of the social sub-committee.

of solutions containing pertungstates and compounds of the several lower valency states as well as a wide range of solutions containing 6-valent tungsten. All were unsuccessful.

Dr. T. P. Hoar, in the course of his reply, referred to the considerable beneficial influence in the experiments of the use of interrupted d.c. This arose, not so much because it increased the amount of tungsten in the deposit and the cathode current efficiency, although it did both to small extents, but largely because of the ability to use higher current density when coating a parent deposit. The higher the current density, the better and sounder the deposit, provided interrupted d.c. were used. The best deposits were at a high c.d. but impoverishment in the cathode layer under ordinary d.c. conditions quickly led to bad conditions.

This was the end of the first day's technical activities and I must say I was rather surprised and a little alarmed at the very high technical and theoretical level at which the discussions had been conducted there was very little which I could get hold of as being of immediately practical use to me in the plating shop, and I had not really been able to understand much of what was said. As this report is unsigned I can say this without fear of retribution. However, I cannot deny that these fundamental theories must be discussed and that they will in the end affect our day-to-day work.

Civic Reception

After dinner the same evening, the whole Conference was entertained to a Civic Reception at the Marine Spa, where we were taken by coach. The provision of transport was a welcome part of the organization as the weather was still unseasonably chilly, with occasional heavy showers of rain. The Mayoral function, at which we had all been most pleasantly entertained, ended at midnight when we were returned to the Hotel. It was then that I made another most interesting discovery about the habits of I.M.F. members attending these Conferences, and that was that a considerable number of them apparently manage to do with not more than two hours sleep a night throughout the Conference, and although I never personally confirmed the statement, I learnt that many discussions continued into the small hours. Nevertheless, and in spite of considerable improvement in the weather, the technical sessions were always very well attended and the discussion was always lively.

On the Thursday morning, under the chairmanship of Mr. H. Silman, the third technical session started with the presentation of a paper on "The Chemical Polishing of Mild Steel by Hydrogen Peroxide-Oxalic Acid Mixtures" by A. Hickling, D.Sc., Ph.D., F.R.I.C., and A. J. Rostron, B.Sc. This again was a subject in which I was generally personally very much interested and I found myself very much in agreement with Dr. J. Edwards, British Non-Ferrous Metals Research Association, when in the course of his opening contribution to the discussion, he recalled that great things were promised for electrolytic and chemical polishing not so many years ago, but as the limitations of the processes became known enthusiasm waned. They seemed to have survived this period of disillusionment and there was now a great revival of interest, with most activity perhaps concentrated on the treatment of aluminium and its alloys.

The bulk of the discussion of this paper was devoted to the mechanism of the smoothing action of the solution described by the authors, particular reference being made to earlier contributions by Dr. T. P. Hoar and Dr. J. Edwards on these subjects. It is impossible to do justice in a few words to all the interesting points that were raised, but it does appear that we are now nearing a real appreciation of what is involved in these polishing methods, and the time may not be far off when, as envisaged by Dr. K. Sachs, G.K.N. Group Research Laboratories, it will be possible to tailor-make solutions for chemical polishing of almost any metal.

I also found myself in sympathy with Mr. A. W. Brace, Aluminium Development Association, when he urged the need for a cleaning up of the terminology used in this connexion, particularly of the use of the words smoothing, polishing and brightening.

The next paper " The Electrolytic Oxidation of Copper and Copper Alloys in Hot Alkaline Solution " by S. G. Clarke, D.Sc., A.R.I.C., F.I.M., and J. F. Andrew, B.Sc., was of a much more practical nature than some of those which had gone before, and the coating described will doubtless find several applications in practice. The examples of the coating exhibited by the authors showed it to be a very deep velvety black with no perceptible reflectivity.

One of the contributors to the discussion, H. A. Manning, Holmes Plating Co. Ltd., said that it had been difficult up to now to find a black which was both a real black and easy and consistent to apply. He was particularly interested in the possibility of its application to articles in bulk, and wondered whether it would be possible to retain a polish as at the moment this appeared only to be obtainable by a subsequent buffing operation. Dr. Clarke, in the course of his reply, said that they had used lanoline with a lot of parts and the appearance was maintained very well. Up to the present time it was still necessary to use some form of mechanical finish to remove the fibrous growth from the surface of the coating, but a thinner more reflective coating could doubtless be obtained by changing the operating conditions.

The last paper at the morning session related to " The Structure and Growth of Electrodeposits and the Modifications Caused by Brightening Agents " by H. Wilman, D.Sc., Ph.D., F. Inst.P. The discussion on this paper emerged as a series of arguments for and against the theory postulated by the authors concerning the possibility of temperatures of considerable order being encountered at the cathode surface during the course of plating. As a number of people all very much more learned than I failed to agree, or to convince each other, comment from me in this connexion would obviously be superfluous, in fact as it appeared that I was not going to be able to make any worthwhile contribution to the discussion I took the opportunity of paying a visit to the small technical exhibition staged in an adjoining room.

The Exhibition

Among the exhibits were a number which had been staged by the authors of papers to illustrate and to supplement what they had written, thus there were a number of corrosion samples comparing the performance of tin-cadmium plated samples in various corrosive media. There were also some examples of Dr. Clarke's black oxide coating on copper exhibited so as to emphasize the very low reflectivity of this finish. Samples of cadmium plated bolts after corrosion testing, were also shown by Mr. Wallbank.

Some very interesting and impressive examples of components manufactured by electroforming, as described in the paper by Walker, Bentley and Hall, were exhibited by the authors, and there were a number of photographs further illustrating the two paint papers and some X-ray photographs referring to Dr. Wilman's paper.

Mr. Fry showed the contractometer developed by Brenner and Senderoff for the measurement of stresses in electroplates, while the jig used by Hammond and Williams for the same purpose, was also on show.

A useful instrument for the measurement of current density at various positions on the cathode surface, developed by the G.K.N. Group Research Laboratory, was shown, but a full description of it would take more space than is available here.*

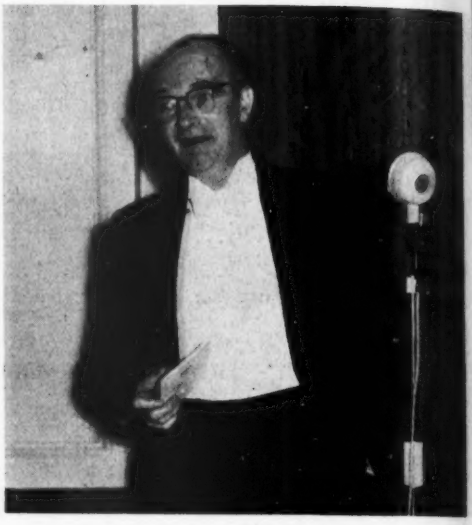
The coating thickness meter developed by The British Non-Ferrous Metals Reasearch Association, which has already been fully described in these pages, was available for trial and there were also two instruments for measuring coating thicknesses exhibited by Solus-Schall Ltd. One of these, the layer thickness gauge, Type 2.090 is designed to measure the thickness of non-magnetic coatings on a magnetic base, thus such coatings as chromium, zinc, cadmium and copper as well as paint and enamel, can be measured, but not nickel or cobalt. The instrument operates on an inductance principle, the test head being a very small magnetic yoke with primary and secondary windings. If the open yoke is brought near a steel sheet the voltage in the secondary winding will increase because of the reduction in demagnetizing effect, and this voltage will reach its maximum when the head is in contact with the steel. The voltage in the secondary coil is therefore a function of the distance between the base and the

A description of this instrument will be published in the next issue of "Metal Finishing Journal".

measuring head, and can be used, to measure the thickness of any superimposed plating layer. This secondary voltage is fed into a bridge circuit and is initially balanced for an unplated specimen. Out-of-balance voltages caused by separation of the head from the base are amplified and fed to a large meter, calibrated directly in layer thickness values.

The other instrument, the Isometer type 2.080 is for measuring the thickness of non-conducting layers, such as paint, enamel, plastics and anodic coatings on a non-ferrous base. In this case the test head is a very small coil which is energized by a high frequency oscillator. The associated magnetic field induces eddy currents in the base material, and their reaction on the coil is used to indicate the separation of the probe from the base metal. The frequency of the energizing current is chosen so that the conductivity of the base has little effect, and the probe is designed so that its separation from the base by the thickness of the coating layer, is linearly related to the output of the amplifier and the indication on the meter. Measurements can be made on very small areas, both flat and curved.

The provision of these exhibits as a supplement to the technical papers was very valuable and I hope that it is retained as a permanent feature of future conferences. An innovation this year was an art and handicrafts competition, for which a number of members and their wives had entered photographs, drawings, and some remarkable examples of needlework, marquetry and metal-work. These entries were judged by a panel during the Conference, particular successes were gained by Mr. R. A. F. Hammond and Mrs. J. W. Price.



The principal guest at the Conference Dinner, the Rt. Hon. the Earl of Halsbury, proposing the toast of the Institute of Metal Finishing.

At the fourth technical session on Friday morning, the chairman was Dr. G. E. Gardam, and the first paper presented and discussed was " The Barrel Plating of Screw Threads " by A. W. Wallbank, B.Sc., F.R.I.C., and D. N. Layton, Ph.D., M.Sc.; this was a very interesting paper in which the practical difficulties of many aspects of barrel plating were well thought out and the discussion was particularly lively. In the case of screw threads in which size tolerances were critical the question of accurate control and measurement of coating thickness was particularly important and several speakers emphasized the difficulties

The President presents the Johnson Matthey Silver Medal to the joint authors of a paper on "The Electrodeposition of Gold and Other Alloys by a New Method," Dr. G. E. Gardam, (left) and Mr. N. E. Tidswell (right).

encountered in this connexion. These included build-up on leading threads, variations in barrel loads under practical production conditions, and dimensional losses on threads as a result of heat-treatment in uncontrolled atmospheres.

The second paper discussed that morning was "Electroforming in Electronic Engineering" by P. M. Walker, A.U.C.N., N. Bentley and L. E. Hall, B.Sc., A.C.G.I. and was presented by Mr. P. M. Walker. This again was to me an exceedingly interesting paper, and I am only sorry that the amount of space at my disposal for this report will not allow me to give the details of the discussion of this paper and the previous one in full. However, they will in time appear in the Transactions of the Institute where they can be read, but the production of these appears to be such a lengthy process that by the time the Volume appears, much of the topicality of the discussion is lost. I think the most interesting fact emerging from the discussion of this paper, was that the authors considered electroforming to be a suitable process for batch production, and not only for the one or two off as was sometimes stated. As one whose livelihood is bound up in the electroplating industry, I am always pleased to learn of possible new applications or extensions of the process, particularly in view of the large number of alternative finishes and materials which are now seeking adoption.

In the afternoon under the chairmanship of Mr. A. A. B. Harvey, the fifth Technical Session was devoted to the discussion of two papers relating to paint. The first of these "The Electron Microscope in the Study of Paint" by N. D. P. Smith, B.Sc., A.Inst.P. was of a rather fundamental nature, but some of the photomicrographs of pigment particles were most impressive. It was interesting to learn that the microscope used by the author had a limit of resolution of about 50 A.U. and that with this he had been unable to obtain visual evidence of the existence of pores in a paint film, although other evidence suggested they must be present. Dr. J. E. O. Mayne suggested that any capillaries present in a paint film might be expected to have a diameter at their mouths of 20 to 30 A.U.

The second paper had investigated "The Blistering of Paint Films on Steel Surfaces" by A. Nicholson and H. A. H. Jenkins. This paper concerned itself to a considerable extent with the mechanism which led to the production of so-called snail trailing which has been a considerable nuisance, to the motor industry in particular, for many years. Some poignant remarks to this effect were made by Mr. R. J. Brown (Nuffield Central Research Laboratories), who said that the statement by the authors that "there is no water-proof paint," could not be sufficiently emphasized. He felt that more work remained to be done on the permeability of paint films. With the exception of snail trailing most blistering on car bodies occurred at the interface of the colour coat with the undercoats, rather than at the metal/paint interface and he felt that this most frequently occurred under conditions of high humidity, as for example in transit in ships' holds.

Conference Dinner and Dance

The final evening of the Conference was devoted to a formal dinner and dance in which over three hundred took part. This was a most enjoyable function and all the six speakers on the toast list discharged their responsibilities effectively and expeditiously. The toast of the Mayor and Corporation of Torquay was proposed by Mr. R. C. Davies, who as a local resident, had assisted with the on-the-spot organization of the Conference. To this the deputy Mayor, Councillor A. L. Goodrich, replied. The principal speaker of the evening proposing the toast of the Institute of Metal Finishing, was the Rt. Hon. The Earl of Halsbury, who expressed his pleasure at being present once again at an I.M.F. function and hoped that during the course of the discussion on education, which he was to initiate on the following morning, he would be able to tender them some profitable advice.

In replying to the toast the President, Professor J. W. Cuthbertson, paid tribute to all those who had been responsible for the technical and social success of the Conference and he also took the opportunity of presenting two of the Institute's awards. The Johnson Matthey Silver Medal had been awarded jointly to Dr. G. E. Gardam and Mr. N. E. Tidswell, and the Westinghouse Brake and Signal Co. prize went to Dr. Leidheiser of the Virginia Institute of Scientific Research.

The reply to the toast of the Guests, humorously proposed by Mr. H. Silman, was delivered by Professor A. J. Murphy, in the regretted absence, through indisposition, of Dr. Maurice Cook.

Education in Metal Finishing

It was a pity that the discussion of the important subject of the supply and training of new entrants to the metal-finishing industry should have had to take place when many people were on the point of leaving, but in spite of difficulties, a very reasonable number of persons were present to hear Lord Halsbury present his paper on "Metal Finishing—Technique of Technology."

Further contributions from various points of view were made by Mr. J. F. Kayser (Gillette Industries Ltd.), Mr. D. G. Silcock, speaking on

(*continued in page* 278)

The Effect of Aluminium Additions to an Experimental Hot-Dip Galvanizing Bath on the Rate of Attack on Steel*

By N. B. RUTHERFORD, B.Sc., A.I.M.†

(*A Communication from the British Non-Ferrous Metals Research Association*)

Introduction

THE attack of molten zinc on steel is of importance to the galvanizing industry for three reasons: in part it determines the nature of the coating, the rate of dross formation, and the life of the galvanizing kettle. Aluminium additions are frequently made to hot-dip galvanizing baths to improve the appearance and, in certain cases, alter the character (thickness, and proportion and type of alloy layer) of the coating. Consequently, the effect of such an addition on the rate of attack on steel is of practical interest.

Experiments by other workers, at the time of the work described here, have given conflicting results. Thus, while most investigators agree that, as the aluminium content of the galvanizing bath increases, the alloy layers, which form on the work between the outer zinc layer and the steel base and which give some indication of the rate of attack on the steel, become thinner and finally disappear([1-5]), Hall and Kenworthy([6]) report thicker alloy layers when the immersion times of their specimens were over 2 mins.

Conflicting results have also been reported by investigators studying the effect of aluminium additions to molten zinc on the rate of attack on steel by measuring the loss in weight of the steel after immersion for short times (up to 1 hr.) ([6-8, 15]), though what little work has been done for longer times (2-30hrs.) indicates that the rate of attack is reduced by the addition of aluminium ([3,9,10]). There is general agreement that below 480°C. attack is much slower than above and it seems established that at the lower temperatures and for the short times of immersion used in the tests, attack is parabolic in character ([3, 5, 7, 8, 9, 11, 12]).

Some of these discrepancies may be explained by recorded differences in procedure. Thus, in baths with low lead contents and under varying conditions of time and temperature of immersion, the alloy layers are said to disappear when the aluminium content reaches 0.1-0.3 per cent ([1-4, 13]) but in the presence of over 1 per cent lead an aluminium content of 0.6-1.0 per cent is reported necessary([6,14]); and Haughton has shown the iron content of a bath practically free from lead to have a marked effect on the amount of aluminium needed to suppress alloy formation and on the rate of attack on mild steel immersed for 5 min. at 450°C. Thus 0.05 per cent aluminium had no effect on rate of attack, 0.1 per cent aluminium greatly reduced attack with iron-free baths and greatly increased it with iron-saturated baths, and 0.2 per cent aluminium reduced attack with all iron contents([15]).

In practice, however, galvanizing baths are normally used below 480°C., are saturated with iron and contain 1 per cent lead. In the course of some other work, a few new tests have been made, under such conditions, to measure the effect of adding 0.1 per cent aluminium to the bath on the rate of attack on steel. The interest of the tests lies mainly in that they cover much longer periods of immersion (up to 120 hrs,) than in other reported work.

Method

For these tests 10 cm. square specimens were cut from 6 s.w.g. mild steel plate of percentage composition C, 0.16; Si, 0.05; Mn, 0.43; Cu, 0.10. To remove any surface layer effects the specimens were normally pregalvanized and then stripped, pickled, rinsed, dried in hot trichlorethylene and weighed before re-immersion for the test. A few specimens were immersed for test after pickling only, and a few were immersed as received, *i.e.*, with the rolling and annealing scale still present.

The galvanizing bath was electrically heated and maintained at 450±5°C. The steel pot measured 10×3½×12 in. deep and held about 1 cwt. of metal. This was made from pure zinc (99.99+ per cent) together with pure lead (99.99+ per cent) in excess of its solubility limit. Aluminium of commercial purity was added as required. When aluminium was present, frequent dip samples were taken for spectrographic analysis and, with the exception noted in Fig. 1, the content was maintained between 0.09 and 0.11 per cent.

After immersion for the prescribed time, the steel specimens were withdrawn, cooled and the adhering zinc removed completely by immersion in cold 5 per cent sulphuric acid. The acid contained 0.2 per cent arsenious oxide to prevent attack on the steel: tests on mild steel (of percentage composition C, 0.09; Si, <0.05; Mn, 0.30; Cu, <0.10) had shown that this was attacked by the stripping solution at the rate of only 0.00027 gm. per sq. cm. of surface per

* B.N.F.M.R.A. Report R.R.A. 1046P. The experiments recorded in this note are taken from Report R.R.A. 884.

† Former Liaison Officer, B.N.F.M.R.A. London, now at Cam Gears Ltd., Luton.

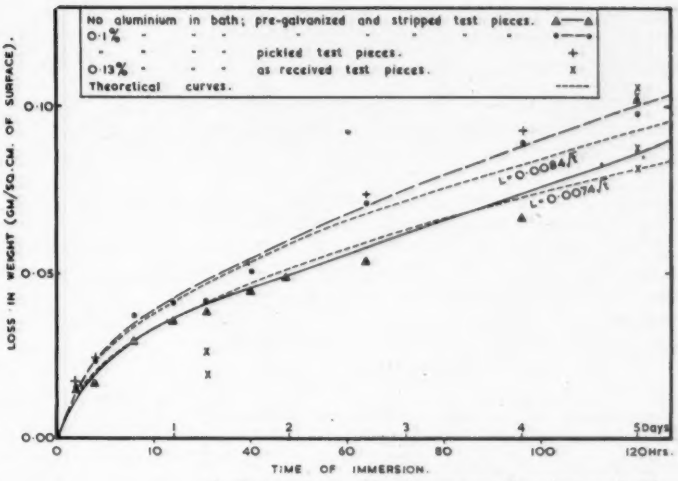


Fig. 1.—Comparison of the loss in weight of mild steel held at 450° C in galvanizing baths free from and containing 0·1 per cent aluminium.

hr.[16]. The specimens were weighed after drying in hot trichlorethylene and the difference from their original weight taken as a measure of the average rate of attack of the galvanizing bath metal on the steel; the measurements were accurate to better than 0.00002 gm. per sq. cm. of surface.

Results

The results of the tests are given in graphical form in Fig. 1. The figure includes two theoretical curves. These show that, for the shorter immersion times, the rate of attack is roughly parabolic whether aluminium is present or not. For the aluminium-free bath the results approximately fit the equation:

$L=0.0074\sqrt{t}$, where L=loss in weight in gm. per sq. cm. of surface.
and t=time in hr.

This is in good agreement with Daniels' short-time tests (up to 100 mins.) with commercial purity zinc and 0.054 per cent carbon steel[7], in which he found:

$L=0.0072\ \sqrt{t}$

With 0.1 per cent aluminium in the bath the results approximate the curve:

$L=0.0084\ \sqrt{t}$.

Thus, the effect of the aluminium has been to increase the rate of attack on the steel by about 13½ per cent.

With 0.1 per cent aluminium present, Daniels' tests[7] gave (by interpolation):

$L=0.0092\ \sqrt{t}$.

The fact that the attack for these shorter immersion times follows approximately a parabolic law, indicates that during this stage attack is diffusion controlled, though whether inward diffusion of the zinc or outward diffusion of iron through the alloy layers is the main factor is not revealed.

For the longer immersion times, however, the experimental curves begin to deviate markedly from the theoretical and towards a higher rate of attack. The appearance of specimens withdrawn after immersion for these times was rougher than for the shorter times and there were many steps on the surface. Furthermore, the zinc and alloy coatings cracked during cooling, and frequently became separated from the steel.

It seems likely, therefore, that the departure from the parabolic curve is caused by sections of alloy layer flaking off while attack is proceeding. Thermal fluctuations could account for this and any movement of the bath would be expected to increase the effect.

The results in Fig. 1 show two other points of interest. First, that the rate of attack on pickled specimens was the same as that on pregalvanized specimens. Second, that scale left on the steel from production processes provides some protection against attack by the galvanizing bath for an immersion time of 32 hrs., but has no significant effect for an immersion time of 120 hrs.

Acknowledgements

The author's thanks are due to the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish this paper, and to Mr. R. W. Thorley for help in the experimental work.

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The Electrolytic and Chemical Polishing and Brightening of Aluminium and its Alloys

(*continued from page* 258)

trisodium phosphate in water. The bath operates at around 80°C., using initial current density of 40 to 50 amp per sq. ft.—which falls to 25 to 30 amp per sq. ft. and stabilizes with a treatment time of 5 to 10 min. As it is alkaline, a mild-steel tank can be used which cheapens the cost of the installation. A subsequent patent[23] covers the addition of sodium-octyl sulphate to the bath, to reduce the tendency for streaks to be produced from the gas evolved. After brightening, the components may be anodized in a 25 per cent sodium-bisulphate solution at about 5 to 8 amp per sq. ft. and 12 volts at room temperature, but is now more usual to anodize in dilute sulphuric-acid electrolytes (*e.g.* 10 per cent by vol.) at about 24°C. (75°F.). In the brightening process, the length of the etching time in the bath before switching on the current is critical, and should be adjusted to suit the material being treated.

Another interesting alkaline brightening bath is revealed in a French patent[24] comprising electrolytic degreasing followed by a dip in a chromic-/phosphoric-acid bath, followed by brightening for about 10 to 15 min. in a mixture of 60 gm. per l. aluminium phosphate and 100 gm. per l. of sodium hydroxide operated at 80°C. and 50 amp per sq. ft. at 12 volts; there is a further dip in the chromic-/phosphoric-acid bath to remove the smudge film. Final anodizing is carried out in a 12 per cent sulphuric-acid solution using a current density of about 15 amp per sq. ft. at 12 volts. As with the Brytal process mild-steel tanks are suitable.

(*To be concluded*)

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Note: The year given after patent numbers indicates the application date of the patent.

A Plater at Torquay

(*continued from page* 275)

behalf of the Metal Finishing Association, and Mr. A. A. B. Harvey, speaking on the needs of the organic finishing section of the industry. Many other speakers, both industrial and academic, voiced their opinions, and the matter was summed up by Lord Halsbury, who said that the metal-finishing industry must make up its mind as to whether it was a group with problems in common, which could operate collectively. If they decided that such action was possible then it would be necessary for them to get together for their common benefit.

The session concluded with the adoption of a resolution requesting the Council of the Institute to frame an educational policy implementing the findings of the meeting.

Such was the 1955 Conference of the Institute of Metal Finishing at Torquay. Reading over what I have written I am only too conscious that I have failed to do adequate justice to the very great technical value of the discussions at the various sessions, and even where these were of a highly technical nature, I can still claim to have derived considerable benefit from listening to them. During the course of the four days of the Conference, many tens of thousands of words were spoken and put on record, and it has been impossible here to give more than the overall impression left with me on my return to my works and after studying my notes. In addition there was for me the most welcome opportunity of discussing common problems with my fellow platers in a way which never seems possible at the regular section meetings. As an expression of personal opinion I found the whole Conference to be very well organized and to be very well worth the time and money expended in being present. I only hope that I shall be able to attend again next Spring, when I understand the venue is to be Blackpool.

FINISHING

NEWS REVIEW

ROYAL VISITOR AT B.N.F.M.R.A.

Jubilee of Euston Street Laboratories

IN recognition of the fact that this year the British Non-Ferrous Metals Research Association commemorates the twenty-fifth anniversary of the establishment of the laboratories in Euston Street, the Association was honoured on May 23 by a visit by H.R.H. The Duke of Edinburgh. His Royal Highness spent a considerable time in touring the laboratories and showed great interest in the work in progress. At the close of his tour he was presented with a specially bound copy of a Brochure produced to mark the occasion, describing some of the achievements of the Association during the past quarter-century.

In the four subsequent days of the week the laboratories were open to members of the Association.

Reference has already been made in a previous issue of this Journal to the work that B.N.F. is carrying out on behalf of the metal finishing industry, but some of the more recent developments noted during the course of the visit may be mentioned here.

Much of the work of the Chemistry Laboratory relates to the evolution of analytical techniques suitable for use in the control of plating solutions. Typical of these was the use of the ultra-violet spectrophotometer for the estimation of organic constituents in plating solutions, a particular application being the estimation of coumarin in bright-nickel-plating solutions. Although this technique has not yet been fully worked out, it shows considerable promise. Considerable use is also made of ion-exchange resins in separating constituents from plating solutions. This process is particularly well adapted to the removal and estimation of trivalent chromium from chromium-plating electrolyte.

In the Electroplating Laboratory, in addition to the already well publicized work on proprietary bright-nickel-plating solutions, and the accelerated corrosion tests using sulphur dioxide, a number of new researches have recently been initiated. Progress in the investigation of cracking in chromium plate has already been reported by H. Fry in a paper to the annual Conference of the Institute of Metal Finishing reported elsewhere in this issue, and further work on this subject is in hand. Other work in progress is a fundamental investigation of the mechanism of the levelling action of some electroplating solutions, and an attempt to produce finishes on zinc surfaces comparable with the familiar anodized finishes on aluminium.

Corrosion

Work on corrosion has always featured prominently in the Association's research programme and significant progress has been made in this field. After having evolved an alloy which has solved most of the problems of corrosion of steam condenser tubes under normal service, the emphasis of the work has shifted to meeting the difficulties which are being experienced in operating condensers in power stations and oil refineries built on river estuaries where the cooling water is heavily polluted. A major factor to be countered under these conditions is the presence of hydrogen sulphide.

Other corrosion researches in progress relate to the suitability of aluminium alloys for water services and the best conditions for the use of galvanized steel in varying water supplies while work has been commenced in an attempt to verify the presence of a substance in some waters which inhibits pitting corrosion of copper.

INSTITUTE OF VITREOUS ENAMELLERS LAUNCHES NEW SECTION

Good Support at Scottish Meeting

ON Tuesday, May 19, the Institute of Vitreous Enamellers organized a technical meeting at the Ice Rink, Falkirk, which was attended by some fifty enamellers operating plants in the area. The meeting was supported by the presence of the chairman and vice-chairman of the Institute's Council and the chairman of the Technical Committee.

After the technical session at which a report from the Institute's sub-committee on cast iron for vitreous enamelling was presented and discussed, there was an informal general discussion in the course of which it was suggested that action be taken to revive the Scottish Section, whose existence had lapsed during the recent war.

It was unanimously agreed by those present that an application to Council should be made for recognition to be extended to the Scottish section and an interim committee was appointed to administer the section as follows.

Chairman	R. R. Fyfe Smith
Vice-Chairman	J. A. Donaldson
Hon. Secretary	J. B. Booth
Committee	Dr. T. Caulfield
	A. W. Watters
	J. E. MacIntosh

Any persons resident in Scotland associated with the enamelling industry who are likely to be interested in the activities of the Scottish section should communicate with the Hon. Section Secretary, Mr. J. B. Booth, Balbardie Ltd., 110 Hanover Street, Edinburgh, 2.

BIRMINGHAM ENGINEERING CENTRE

IN view of the recent announcement that the Birmingham Exchange buildings have been the subject of purchase by a local property company, the Birmingham Exchange and Engineering Centre have issued a statement to the effect that the present lease does not expire until March, 1961. Furthermore, it is anticipated that the engineering centre will then be accommodated in a new building.

The future of the centre, the committee states, was carefully considered in the light of the present lease before the reconstruction of the Exchange was undertaken, and in view of its initial success, the committee are encouraged that their plans for the future have so far been fully justified.

INSTITUTE OF VITREOUS ENAMELLERS

SECTION OFFICERS

At the annual general meetings of the three sections of the Institute of Vitreous Enamellers held recently, the officers and committees for the 1955/56 session were elected, to take office with effect from October 21, as under:

Midland Section	
Chairman	D. Baldwin
Vice-chairman	G. H. Legg
Hon. Secretary	D. Sleath
Committee	W. Ball
	L. Bayliss
	L. A. Read
Northern Section	
Chairman	C. Swinglehurst
Vice-chairman	S. E. A. Ryder
Hon. Secretary	O. Dreyer
Committee	P. Rogers
	G. Redman
	J. Ward
Southern Section	
Chairman	J. J. Guy
Vice-chairman	B. B. Kent
Hon. Secretary	J. Hooper
Committee	A. B. Kent
	J. H. Gray
	W. E. Ebel

AUSTRALIAN CORROSION MEETING

THE University of Melbourne has announced that it is to hold a symposium on corrosion next December. Plans for this symposium have been made the responsibility of a committee representing a number of interested scientific bodies under the chairmanship of Professor H. K. Worner, and arrangements are well in hand. It is anticipated that some thirty papers will be presented and discussed, dealing with numerous aspects of the subject, including fundamental studies, corrosion prevention, corrosion under buried or immersed conditions, and corrosion problems special to various industries.

Information on the symposium is obtainable from the Secretary of the organizing committee, Mr. G. M. Willis, Department of Metallurgy, University of Melbourne, Carlton, N.W. Australia.

TECHNICAL AND INDUSTRIAL APPOINTMENTS

Mr. G. F. Ingham Clark has been appointed as Sales Director to the Board of **Pinchin, Johnson & Associates Ltd.**, the well known paint manufacturing organization. He joins the Board at the age of 50, from his present position as General Manager of **Robt. Ingham Clark and Co.** and their associates **R. Gay and Co.**

Mr. G. F. Ingham Clark was educated at Cheltenham College and the University of Neuchatel, first joining the family company of Robt. Ingham Clark in 1923.

After distinguished service during the war Mr. Ingham Clark resumed his duties in 1945 with **Robt. Ingham Clark and Co.** as General Manager.

* * *

Following the appointment of Mr. G. F. Ingham Clark to the Board of **Pinchin Johnson & Associates Ltd.**, the management of the associated companies, **Robt. Ingham Clark and Co.**, and **R. Gay and Co.** is to be the joint responsibility of Mr. G. S. Richards and Mr. D. J. S. Shaw.

Mr. Gordon Richards entered the paint trade in 1931 in the Advertising department of the parent company.

Mr. David Shaw received his initial training under the apprenticeship scheme at the Silvertown Works, starting in 1935.

* * *

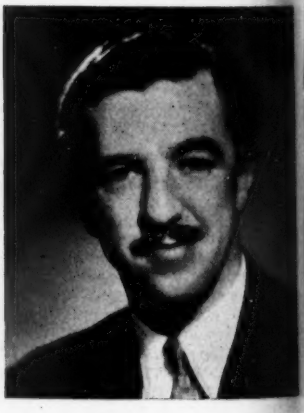
Mr. J. H. Hawkey has been appointed general manager of **Sir W. A. Rose and Co. Ltd.**, one of the Berger-Group of paint companies. He has been with the group for many years and has had considerable experience in decorative and industrial paints of all types. For the past two years he has been the Berger Group representative in the Middle and Far East.

MR. G. F. INGHAM CLARK.

Mr. W. E. Wornum, M.C., B.Sc., A.R.C.S., F.R.I.C., has joined the technical staff of **Smith and Walton, Ltd.**, as deputy technical director. From 1940-44, he was president of the Oil and Colour Chemists' Association of which he had been for many years research and development officer. He has been closely associated with the work of the Paint Research Association since its early days and is the present chairman of its Technical Advisory Committee. A Member of its Council since 1937, he was vice-president from 1945-47. He was leader of the British Intelligence Objectives Sub-Committee which investigated the German paint industry after the war. He has published a number of original papers in various scientific journals.

MR. G. S. RICHARDS.

MR. D. J. S. SHAW.



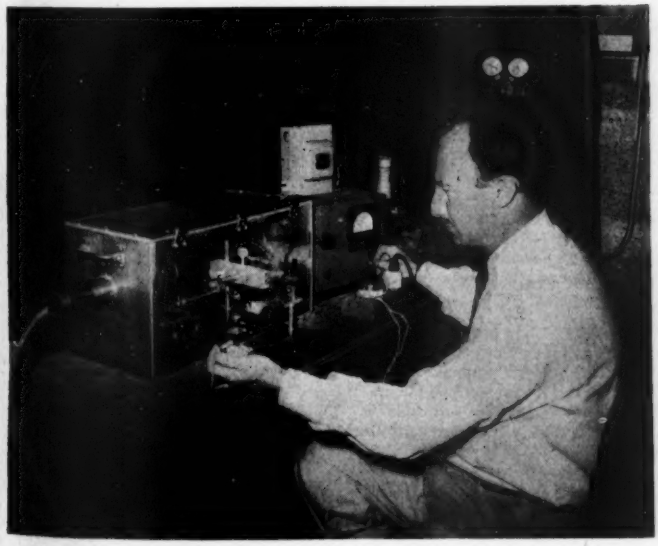
New Abrasive Jet Method for Evaluating Organic Coatings

A SIMPLE, rapid method for measuring the abrasion resistance of organic coatings on metals has recently been developed by A. G. Roberts, W. A. Crouse, and R. S. Pizer of the U.S. National Bureau of Standards. Essentially, the method determines, under controlled operating conditions, the time required for a high-speed jet of fine abrasive particles to abrade through the coating to the substrate. Development was sponsored by the U.S. Navy Bureau of Aeronautics in connection with a programme for the production of highly durable, scuff-resistant finishes for naval aircraft. Because the instrument readily simulates a variety of service conditions, the new procedure can be used to determine abrasion resistance on all types of protective coatings, regardless of gloss, colour, thickness or surface area.

Abrasion resistance is often one of the most important factors in the service performance of protective coatings. Until recently thoroughly reliable methods for determination of this property have been lacking. Several abrasion test procedures are available in which loose particles fall, rub, or are blown against the test specimen. Although the new abrasive jet method is similar in principle to these methods, it permits greater ease and rapidity in evaluating materials and better reproducibility because it does not depend upon abrading an area of definite size and uses a continuously fresh supply of abrasive particles under closely controlled conditions. The end point in this method is the first show of bare metal and is readily detected when coating and substrate differ in colour, as is usually the case; otherwise, inspection with a hand lens can be used.

In the abrasive jet method, carbon dioxide gas under controlled pressure propels an abrasive powder from a vibrating storage chamber through a nozzle to impinge at high speed upon the test specimen. A solenoid valve operated with a manual switch turns the flow of the abrasive powder on or off. The mounting arrangement for the test specimen and nozzle assembly permits rotational, back and forth, or up and down adjustment, while the angle between the nozzle tip and surface to be abraded is adjusted by a graduated rotating disc attached to the nozzle shaft. A specially calibrated taper gauge permits rapid and accurate adjustment of the nozzle-to-specimen distance at abrading angles from 20 to 90 deg. The specimen holder and the nozzle assembly with its adjusting parts are housed in a rectangular brass chamber with a transparent plastic front door and top.

The spent abrasive particles and coating debris are removed through a vacuum exhaust outlet at one end of the test chamber. Rapid monitoring of the abrasive flow rate is accomplished by a weighing tube that has a rubber diaphragm with a hole to accommodate the nozzle tip at one end and a diaphragm of ordinary filter paper at the other end to permit escape of gas while trapping the abrasive particles.



Although operating conditions can be varied to accommodate extreme differences in materials, it is usually desirable to use a nozzle-coating distance of 0.04 in., a gas pressure of 40 lb. per sq. in., a flow rate of approximately 0.15 gm. per second, and abrading angles of 90 or 45 deg. The 90-deg. angle simulates the leading-edge type of erosion encountered by aircraft in flight, while the 45-deg. angle simulates scuffing wear which aircraft receive during maintenance operations when they are walked on, struck, or scraped by hose nozzles.

The abrasion time for a given material depends on the test conditions; it increased almost linearly with increasing nozzle - to - coating distance, decreases with increasing pressure, and decreases with decreasing angle of abrasion from 90 down to about 30 deg. At smaller abrading angles, the abrasion time rises again.

In the studies at the U.S. National Bureau of Standards, the abrasive jet method has been found to distinguish significantly between materials difficult to differentiate by qualitative means. Although the degree of correlation with actual service performance has not yet been definitely established, work toward this end is now in progress.

Abrasive jet equipment developed recently at the U.S. National Bureau of Standards for measuring the abrasion resistance of an organic coating on metal. Carbon-dioxide gas under pressure propels an abrasive powder from a vibrating storage chamber through a jet nozzle and onto the test specimen. The time required to abrade through a particular test specimen is a measure of its abrasion resistance and depends on such operating conditions as nozzle-to-coating distance, gas pressure, and the angle at which the abrading particles impinge upon the coating, as well as on the intrinsic abrasion resistance of the coating.

OXIDATION OF METALS

Summer School in Corrosion

A SUMMER School will be held at Battersea Polytechnic from July 19 to 22, 1955, the topic being the "Oxidation of Metals."

The following aspects of the subject will be considered: Theoretical principles of dry corrosion and anodic oxidation, oxidation and scaling of heat-resisting steels, alloys for electrical heating elements, nickel-base alloys for high-temperature use, oxidation resistance of the rarer metals, diffusion coatings for resistance to oxidation, and the effect of gases on high-temperature oxidation.

The fee for the course will be £3 3s. If required, accommodation during the course is available at the Polytechnic Hostel for an inclusive charge of £5 5s.

REPRESENTATION OF BATTELLE IN U.K.

The Battelle Memorial Institute of Columbus, Ohio, U.S.A., has announced that they have appointed Robert Q. Wilson, to take over their representation in the United Kingdom. Mr. Wilson will be in charge of the Institute's recently registered office in London, **Battelle Institute Ltd.**, 46, Bryanston Street, London, W.1., and will maintain liaison for British firms sponsoring research at Battelle laboratories in Columbus, Ohio, Geneva, Switzerland, and Frankfurt/Main, Germany.

Dr. H. E. Zentler-Gordon, who up to this time has acted as U.K. representative for the Institute as well as for the Battelle Development Corporation, Columbus, Ohio, will henceforth act as the General Manager of the **Battelle Development Co. Ltd.**, also at the Bryanston Street address, which was incorporated a few months ago to take over the work of Battelle Development Corporation in this country and Scandinavia.

The London Office of **Battelle Institute Ltd.**, was established for the convenience of firms in the United Kingdom in need of contract research facilities of the type provided by the Institute's laboratories. In addition to London, other offices are maintained in Paris, Milan, and Madrid.

TRADE and TECHNICAL PUBLICATIONS

Of two leaflets received from **The Pyrene Co. Ltd.**, Metal Finishing Division, Great West Road, Brentford, Middlesex, the first describes spray gun Bonderizing, which is intended for use on good quality steel sheet where production circumstances or component shape render the installation of orthodox Bonderizing plants impractical. The solution is applied using an ordinary clean paint spray gun fitted with a feed cap, and the resultant coating compares exactly with that produced by more orthodox methods.

The second leaflet describes the Pyroclean No. 101 emulsion type cleaner. This is a degreasing agent used in aqueous solution at 160 deg. F. and is intended for use in the cleaning section of fully-automatic plant.

The Nickel Bulletin, Vol. 28 No. 2 for February, 1955, contains among a number of other abstracts and current published information on nickel and its alloys reference to a paper by Brenner on the electroless deposition of nickel and cobalt. The abstract reviews at length the original paper which was published in Metal Finishing, 1954, Vol. 52, Nov. and Dec.

The current issue of **Jenolite News** contains further references to the use of Jenolite products in the removal and the prevention of rust and corrosion products. These range from advertising signs in America and pipes for Canadian ice rinks to piers at British seaside resorts, and ornately decorated iron four-poster bedsteads for African tribesmen.

Furane Cements: Technical Bulletin No. 4 issued by Corrosion Proof Products Ltd., 37, Portman Square, deals with developments in furane resin cement. In particular reference is made to the company's Corro-Proof "FR" cement, for which a new method has been developed by the company's technical staff, of preparing the cement fillers into which the acid hardener is compounded. This new method, ensures the uniform distribution of the hardener, and results in a stable product in which the catalyst will not expend itself when retained in store. The main advantages claimed are greater uniformity in the mixed cement with consequent improved ease of application etc.

Bulletin No. 5 also just issued by the company, explains in simple terms the measuring of *p*H value. It has been issued because in the company's work of designing and constructing effluent treatment plants an explanation of *p*H value has frequently been asked for.

Exhaust Equipment: A number of illustrated leaflets have been received from Turner and Brown Ltd., Bolton, describing the range of "Turbo" exhaust fans manufactured by the company. A feature of this equipment is that it is constructed entirely in P.V.C. Fans are available for volumes of 300 to 3,000 cu. ft. per min. driven by single- or three-phase motors. These fans are silent in operation and are virtually unaffected by corrosive fumes of all types. The company also manufactures P.V.C. ducting, fume hoods and chimneys.

JENOLIZING OFFERS RANGE OF PHOSPHATING PROCESSES

The **Jenolizing Co. Ltd.**, one of the Jenolite Group of Companies, have announced that they are now manufacturing and marketing processes covering the entire phosphating field. These processes, applicable by immersion or spray plant, may be split into two main types—unaccelerated and accelerated. Unaccelerated solutions, implying slow rates of crystal growth, favour the development of coarsely crystalline coatings. Accelerated solutions, on the contrary, tend to spread rapidly over the steel surfaces and restrict pickling action. Thus, these coatings are usually finer in texture, lighter in weight and dissolve smaller quantities of the surface metal than their unaccelerated counterparts.

The Jenolizing range employ manganese, zinc and iron phosphates forming tightly adherent, densely packed, insoluble, inert, crystalline phosphate coatings on ferrous metal surfaces. They are coded as follows: JM (unaccelerated manganese), JAM (accelerated manganese), JAZ (accelerated zinc), and JF (unaccelerated iron). While producing a complete range, the Jenolizing Company are especially concerned with developing the scope of manganese processes, since these are claimed to give superior paint adhesion and anti-corrosion protection.

The Jenolizing Company also produce a process, known as COP, for treating aluminium and its alloys. Its purpose is to replace the natural oxide film, which is not normally a satisfactory base for paint, with a coating which greatly improves adhesion and inhibits corrosion. The coatings are unaffected by bending or rolling: sheets can be bent to sharp angles without diminishing the protective action of the coatings. In addition to bonding paints, lacquers and synthetic enamels, the coatings lend themselves to dye finishing in a wide range of colours.

Latest Developments in PLANT, PROCESSES and EQUIPMENT

Two-Gun Hot-Spray Unit

WITH the introduction of their new Ecco H3B hot-spray unit, the Atlas Diesel Company Ltd., Wembley, claim continuous performance with two guns used independently.

This new unit is a modification of the old unit and an adaptor has been fitted to the side of the distributor block. This adaptor allows two spray guns to be fed from the unit ensuring compensation of the fluid pressure in both lines. The new unit is fitted with a 3½ kW. heater instead of the old 2½ kW. heater and still maintains temperature and pressure with two guns as it previously did with one.

An additonal feature of this modification is that existing users of the H3B can have their plants modified for two-gun operation by the purchase of a higher powered immersion heater and the adaptor, apart from the additional spray guns and hoses.

The fluid pump now incorporates a gland of a different type and design which removes the possibility of the gland breaking down as has been the case in the past when the plant has not been properly maintained or run at too high a pressure. Owing to the design of the adaptor, it is not recommended that pigmented materials are used in the two gun plant unless regular and careful cleaning of the adaptor is carried out.

Description of Unit.

The unit, shown in Fig. 1, consists of three main sections:

1. pump section (upper part), 2. element section (intermediate part), 3. water section (lower part).

The pump section includes the paint pump which is driven from a three- or single-phase a.c. flameproof electric motor by vee ropes, the coupling plinth with cocks and connections for paint hoses, two-gun adaptor unit and thermometer and gauge for controlling the temperature and pressure of the paint. The element section includes a one-phase 3,500 watt element, a thermostat with signal lamp and connections for the air hoses to the spray guns and for the paint coil. The thermostat is manually operated with a knob on the intermediate part of the unit. The water section includes the vessel in which the elements, the paint coil and the pipe from the thermostat are suspended with a water funnel, a water level indicator pipe and a drain cock.

The three sections are held together by means of eccentric locks. In use the unit is attached to a pressure container, spray guns and air transformer. If the unit is to be used in a spray booth, an automatic pressure switch is incorporated. The pressure switch is regulated to switch off at an air pressure of 15 lb. per sq. in. and it is used as a protection against possible ignition of fumes from the spray guns, or the paint shop in general.

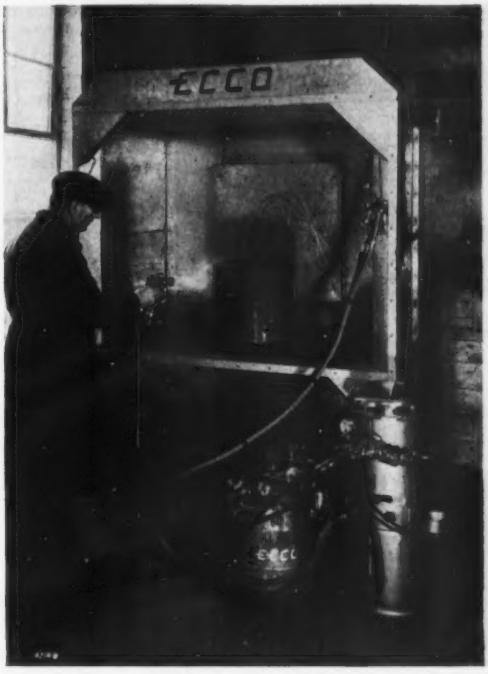


Fig. 1.—Two-gun hot-spray unit

The unit occupies less than 2 sq. ft. of floor space and conforms to the Factory Act regulations.

New Fungicide to combat Paint Discoloration

RECENT surveys have shown that the discoloration of paint and the failure of the film, particularly in buildings of high humidity, is often due to attack by fungus rather than ordinary dirt.

The Nuodex organization, research pioneers in this field, has carried out intensive studies on the subject, successfully isolating as many as 30 different fungi which flourish on paint films. The research has resulted in the introduction of a new fungicide, Nuodex 321.SS, which is completely soluble in mineral spirits and compatible with emulsion paint systems, and effectively precludes such premature decorative loss of the paint.

The Nuodex fungicide has already proved successful for the combat of such paint deterioration both in industry and in the home, and recently it has shown its value in numerous industrial establishments in

which high humidity conditions presented problems of painting costs—breweries for example. Previously, normal emulsion paint had lasted for about two weeks in the humid atmosphere. The incorporation of Nuodex 321.SS fungicide in similar emulsion paint raised this interval to nearly three months, with a corresponding reduction in repainting overheads.

It has been found that some paint formulations actually helped mould growth, the paint serving as a source of food for the fungi. This necessitated the study of individual ingredients in paint compounds and the influence each had on mould susceptibility. The ideal anti-fungus paint is therefore formulated accordingly and reinforced by an effective fungicide.

Nuodex fungicide is permanent and insoluble in water and will neither evaporate nor crystallise from the paint film on exposure. It will remain fully effective for the service life of the paint and is equally successful in the home kitchen and bathroom, factories where high humidity prevails, and outdoors in a humid climate.

The Nuodex Fungicides are manufactured by Nuodex Limited, Birtley, Co. Durham and are distributed by Durham Raw Materials Limited in the following areas:—1-4 Great Tower Street, *London, E.C.*3., 1 Booth Street, Albert Square, *Manchester* 2., 180 Hope Street, *Glasgow, C.*1.

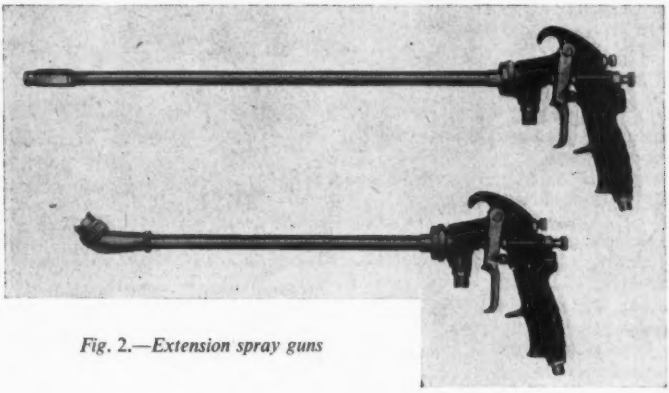


Fig. 2.—*Extension spray guns*

Heat-resisting Stove Grid Enamel Frit

THE O. HOMMEL Co., Pittsburgh 30, Pa., recently announced that a new enamel frit made especially for stove grids, is now available. Listed as frit No. 1625 this new cast iron leadless clear frit is said to give smooth texture results, and to have remarkable durability, resisting not only direct flames, but also extreme thermal shock.

Enamels in a wide vairety of pastel colours in addition to the conventional black, can be produced by the inclusion of suitable colouring oxides at the mill.

The new finish has performed well under accelerated testing under high flame heat and severe shock and in addition, it is a very workable enamel, with a wide firing range.

Concrete Floor Paint

A COLOURED rubber paint specifically formulated to meet the demands of industrialists, who wish to protect and decorate new and old concrete floors, has recently been introduced by Allweather Paints, Ltd., 36, Great Queen Street, London, W.C.2.

Its use on concrete floors eliminates dust and being alkali resistant this paint can even be used on 14-day old concrete floors without fear of breakdown.

Its tough rubber film resists hard wear and since the paint is very quick drying the freshly painted floor is out of commission for only a very short time.

Known as Pitan Concrete Floor Paint this coating is available in a wide colour range. The manufacturers recommend the application of one (dark shades only), two or three coats to provide a dust-free surface which can be repeatedly washed without deterioration.

Pitan Concrete Floor Paint covers 30/50 square yards per gallon and is available in a range of colours.

Extension Spray Guns

B.E.N. PATENTS LTD., High Wycombe, Bucks., are manufacturing two extension spray guns (Fig. 2) Model WHX—360 deg. Circular is designed for the spraying of the inside surfaces of pipes and tubing, etc.; the minimum diameter of opening into which the extension can be inserted is ¾ in. Four nozzle settings are available from a 360 deg. circular spray to a segment spray. Extension tubes of from 1 to 5 ft. are common to all settings. Special lengths from 5 to 10 ft. can be obtained if required.

Model WHX—45 deg. angle, the second type, is for use when the spray must be at a 45 deg. angle. It sprays forward from the gun nozzle in the orthodox manner and the spray head may be rotated a full circle in relation to the gun extension.

The spray formation is adjustable from fan to round and *vice-versa* by rotating the spreader cap half a turn. The minimum diameter of opening into which the extension can be inserted is 1¼ in. Extension tubes are available in the same lengths as the first model.

All spray heads on both WHX—360 deg. circular and WHX—45 deg. angle spray guns are interchangeable on any length of extension.

Emulsion Cleaner

A RECENT addition to the range of commercially available emulsion cleaners has been Spiero 101, produced by E. Spiero Chemicals Ltd., Wellington, Surrey. This cleaner is operated at room temperature and is claimed to remove all types of surface contamination by immersion for up to five minutes followed by a water rinse.

Ordinary mild steel containers are suitable for the cleaner which is non-toxic and without action on ferrous or non-ferrous metal surfaces. Application can be by immersion, spraying or brushing.

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